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THE STARFISHES OF THE HAWAIIAN ISLANDS.

By WALTER K. FISHER,

*Acting Instructor in Zoology, Leland Stanford Junior University.*

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## CONTENTS

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	Page.
Introduction.....	989
Synopsis of Hawaiian starfishes.....	991
List of <i>Albatross</i> dredging stations at which starfishes were secured, with the species taken at each.....	995
Relationships of the Hawaiian starfish fauna.....	997
Species common to the Hawaiian Islands and to the Eastern Archipelago, Indian Ocean, Japan, Polynesia, or Australia.....	998
Species common to the Hawaiian Islands and to the west coast of America.....	998
Species peculiar to the Hawaiian Islands which have nearly related species in Japan, China, or in the Eastern Archipelago.....	999
Species peculiar to the Hawaiian Islands which have nearly related species in the Indian Ocean.....	999
Species peculiar to the Hawaiian Islands and the apparently nearest relatives of those species.....	1000
Description of Hawaiian Asteroidea.....	1001
Explanation of descriptive terms.....	1118
Bibliography.....	1120
Explanation of plates.....	1122

# THE STARFISHES OF THE HAWAIIAN ISLANDS.

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## INTRODUCTION.

The specimens upon which the following report is based were collected by the U. S. fisheries steamer *Albatross* among the Hawaiian Islands during the spring and summer of 1902. A small collection taken off the south coast of Oahu by the *Albatross* in 1891 has likewise been examined, and there must also be added a single example of "*Goniiodiscus*" *sebæ*, collected by Mr. H. W. Henshaw in the vicinity of Hilo, Hawaii. Altogether the collection numbers very nearly 1,650 specimens, and includes 60 species, of which 52 are new to science, 5 are for the first time recorded from the Hawaiian Islands, and 3 are too young or in too poor condition for naming. In other words, the *Albatross* took but 1 species that had been previously reported from the region. Ten species which had been recorded were not secured by the *Albatross* expedition.

The present report may be considered a monographic account of Hawaiian starfishes which occur between the shore and the thousand-fathom line. In their proper places I have listed the 10 species already recorded from the islands which were not secured by the *Albatross*. It is certainly surprising that such forms as *Archaster typicus*, *Gymnasteria carinifera*, *Asterina granulosa*, *Culcita arenosa*, or *Heliaster multiradiata*, all very shallow-water forms and usually occurring on shores or reefs, were not taken. The most important collecting grounds in the future will be the very shallow water near shore, on the windward sides of the islands. If hempen tangles are dragged over the bottom, undoubtedly other widely distributed species will be found. Coral reefs (not the exposed ones) should be most prolific.

I have included keys, and in a chapter at the end of the article have listed the principal technical terms; but the general naturalist will find, as a rule, that the figures of the whole animal are a quicker and surer means of identification. Unfortunately a number of the shallow-water species can not be figured.

The arrangement of families in this report does not follow exactly that of any previous author, but in general may be said to be modeled after Sladen and Perrier as modified by Verrill. It is very difficult to arrange the so-called families of starfishes satisfactorily in serial order, just as it is difficult in other groups. Thus, in placing the Luidiidæ between the Astropectinidæ and Pseudarchasteridæ, it is not

meant that the family holds an intermediate position, because nothing could be much farther from the truth. But since the Luidiidae are a very specialized offshoot from the proastropectinoid stock, there is no other position for the group. Similar apologies should be made for the Benthoplectinidae and the Archasteridae.

In the matter of the orders I have made a compromise between Sladen's and Perrier's and Verrill's modifications of these. Sladen's Phanerozonia is used in nearly the same sense in which he employed the term in the "Challenger Asteroidea." The Linckiidae, being phanerozoniata, are taken out of Sladen's Cryptozonia and placed in the Phanerozonia, in which order they undoubtedly belong; while the Asterinidae (and Anseropodidae) being cryptozoniata, are removed from the Phanerozonia. I believe Perrier's arrangement of the cryptozoniata families under two orders (he has apparently abandoned the Velata) is rather more felicitous than that of Sladen under one large heterogeneous order (Cryptozonia), and I have consequently followed Perrier with small modifications. It must be remembered, however, that there is a great difference of opinion concerning the extent of the orders of Asteroidea. Some writers follow Sladen and some Perrier. As pointed out recently by Professor Verrill (1899), Perrier's Paxillosa and Valvata (=Phanerozonia emended) are decidedly artificial groups. I do not go so far as Professor Verrill in considering them suborders, because unless some more fortunate grouping of families is devised, the difficulty is merely temporarily pigeon-holed.

Returning to the families, it will be noted that I have followed Verrill in dismembering the great "family" of the Archasteridae. I have accepted most of Verrill's modifications and have raised the Pseudarchasterinae to family rank. I can not agree with Professor Verrill that the Pontasterinae constitute a subfamily of the Plutonasteridae, but have relegated the group to the Benthoplectinidae (=Pararchasterinae Sladen), a position more nearly in accord with the views of Sladen. The sequence of families is new so far as the Phanerozonia are concerned. The order starts with the more specialized paxillose forms, with very well developed superambulacral ossicles, and proceeds through those in which the paxillae are often rudimentary or reduced and the superambulacral plates not always present to those in which the latter are always absent. Then, beginning with the Mediasterinae, the transition is gradual toward forms with less paxilliform plates, to those with granular or smooth abactinal plates, and bivalved or foraminate pedicellariae; then to the skin-covered forms, with stellate or stellate-reticulate abactinal skeleton and low bivalved pedicellariae. The Linckiidae, though placed at the end, are in many respects distinctly related to some of the Goniasteridae. They often have excavate pedicellariae. The Gymnasteriidae are rather intermediate forms. In the Spinulosa and Forcipulata the sequence is practically that given by Perrier. The Velata are merged with the Spinulosa. In many respects the classification of the Asteroidea is difficult, especially on account of the number of more or less perfect transitional forms which render family boundaries extremely unstable.

So far as I am aware there have been no special papers on Hawaiian starfishes. The few references are widely scattered and a number of records are given second hand, the original citation being unknown to me. A number of records are very incidental in mention, and it is probable that a few have escaped notice. A bibliography of papers quoted in the following report is appended.

The writer had the good fortune to be a member of the scientific staff during the expedition, and in case of most species made color notes while the animals were still fresh. Ridgway's "Nomenclature of Colors for Naturalists" was used.<sup>a</sup>

## SYNOPSIS OF HAWAIIAN STARFISHES.

[Those marked with an asterisk (\*) were not taken by the *Albatross* expedition.]

## Order Phanerozonia Sladen.

## Family Astropectinidæ Gray.

Genus *Astropecten* Schulze.

*Astropecten polyacanthus* Müller and Troschel.

*Astropecten velitaris* Von Martens.

*Astropecten ctenophorus*, n. sp.

*Astropecten pusillulus*, n. sp.

*Astropecten productus*, n. sp.

*Astropecten callistus*, n. sp.

Genus *Ctenophoraster* n.

*Ctenophoraster hawaiiensis*, n. sp.

Genus *Tritonaster* n.

*Tritonaster craspedotus*, n. sp.

Genus *Psilaster* Sladen.

*Psilaster attenuatus*, n. sp.

Genus *Psilasteropsis* n.

*Psilasteropsis cingulata*, n. sp.

Genus *Dipsacaster* Alcock.

*Dipsacaster nesiotes*, n. sp.

Genus *Papagiaster* n.

*Patagiaster nuttingi*, n. sp.

## Family Luidiidæ Verrill.

Genus *Luidia* Forbes.

*Luidia hystrix*, n. sp.

*Luidia magnifica*, n. sp.

*Luidia brevispina* Lutken.\*

## Family Pseudarchasteridæ Fisher.

Genus *Pseudarchaster* Sladen.

*Pseudarchaster myobrachus*, n. sp.

*Pseudarchaster jordani*, n. sp.

## Family Benthoplectinidæ Verrill.

## Subfamily Pontasterinæ Verrill.

Genus *Cheiraster* Studer.

*Cheiraster snyderi*, n. sp.

*Cheiraster horridus*, n. sp.

*Cheiraster inops*, n. sp.

<sup>a</sup>I am indebted to Dr. Charles H. Gilbert, naturalist in charge of the Hawaiian explorations, and to Prof. A. E. Verrill, of Yale University, for advice in my work on this collection and assistance in the determination of difficult species, and I desire to acknowledge my obligations also to Mr. Henry W. Fowler, of the Philadelphia Academy of Natural Sciences, and to Mr. Wilfred H. Osgood and Mr. Nelson H. Kent, of the U. S. Biological Survey, for copies of several original descriptions and photographs of three small specimens.

## Order Phanerozonia Sladen—Continued.

## Family Archasteridæ Viguiér.

Genus Archaster Müller and Troschel.

Archaster typicus Müller and Troschel.\*

## Family Goniasteridæ Forbes.

## Subfamily Mediasterinæ Verrill.

Genus Mediaster Stimpson.

Mediaster ornatus, n. sp.

Genus Nereidaster Verrill.

Nereidaster bowersi, n. sp.

## Subfamily Goniasterinæ Verrill.

Genus Pentagonaster Gray.

Pentagonaster ammophilus, n. sp.

Genus Tosia Gray.

Subgenus Plinthaster Verrill.

Tosia (Plinthaster) ceramoidea, n. sp.

Subgenus Ceramaster Verrill.

Tosia (Ceramaster) micropelta, n. sp.

Genus Astroceramus n.

Astroceramus callimorphus, n. sp.

Genus Calliderma Gray.

Calliderma spectabilis, n. sp.

Genus Calliaster Gray.

Calliaster pedicellaris, n. sp.

Genus Gilbertaster n.

Gilbertaster anacanthus, n. sp.

## Subfamily Hippasteriinæ Verrill.

Genus Evoplosoma n.

Evoplosoma forcipifera, n. sp.

## Subfamily Leptogonasterinæ Perrier.

Genus Antheniaster Verrill.

Antheniaster epixanthus, n. sp.

## Subfamily Goniiodiscidinæ, new name.

Genus Goniiodiscides, new name.

Goniiodiscides sebæ (Müller and Troschel).

## Family Pentacerotidæ Gray.

Genus Pentaceros Schulze.

Pentaceros hawaiiensis, n. sp.

Genus Nidorellia Gray.

Nidorellia armata (Gray).\*

Genus Asterodiscus Gray.

Asterodiscus tuberculosus, n. sp.

Genus Culcita Agassiz.

Culcita arenosa Perrier.\*

## Order Phanerozonia Sladen—Continued.

## Family Linckiidae Perrier.

Genus *Ophidiaster* Agassiz.

- Ophidiaster lorioli*, n. sp.
- squameus*, n. sp.
- triseriatus*, n. sp.
- sclerodermus*, n. sp.
- tenellus*, n. sp.
- rhabdotus*, n. sp.

Genus *Leiaster* Peters.

- Leiaster callipeplus*, n. sp.

Genus *Linckia* Nardo.

- Linckia diplax* (Müller and Troschel).
- multifora* (Lamarck).\*

Genus *Nardoa* Gray.

- Nardoa ægyptiaca* (Gray).\*

## Family Gymnasteriidae Perrier.

Genus *Gymnasteria* Gray.

- Gymnasteria carinifera* (Lamarck).\*

## Order Spinulosa Perrier.

## Family Asterinidae Gray.

Genus *Asterina* Nardo.

- Asterina granulosa* Perrier.\*

## Family Anseropodidae n.

Genus *Anseropoda* Nardo.

- Anseropoda insignis*, n. sp.

## Family Echinasteridae Verrill.

## Subfamily Echinasterinæ Viguiet.

Genus *Henricia* Gray.

- Henricia robusta*, n. sp.
- Henricia pauperrima*, n. sp.

Genus *Echinaster* Müller and Troschel.

- Echinaster*, sp.

## Subfamily Valvasterinæ Viguiet.

Genus *Valvaster* Perrier.

- Valvaster striatus* (Lamarck).

## Family Mithrodiidae Perrier.

Genus *Mithrodia* Gray.

- Mithrodia bradleyi* Verrill.

## Family Myxasteridae Perrier.

Genus *Asthenactis*, n.

- Asthenactis papyraceus*, n. sp.

## Family Pterasteridae Perrier.

Genus *Pteraster* Müller and Troschel.

- Pteraster reticulatus*, n. sp.

## Order Spinulosa Perrier—Continued.

## Family Pterasteridæ Perrier—Continued.

Genus Hymenaster Wyville Thomson.

Hymenaster pentagonalis, n. sp.

Genus Benthaster Sladen.

Benthaster eritimus, n. sp.

## Order Forcipulata Perrier.

## Family Zoroasteridæ Sladen.

Genus Zoroaster Wyville Thomson.

Zoroaster spinulosus, n. sp.

## Family Heliasteridæ Viguier.

Genus Heliaster Gray.

Heliaster multiradiata (Gray).\*

## Family Asteriidæ Gray.

Genus Coscinasterias Verrill.

Subgenus Distolasterias Perrier.

Coscinasterias (Distolasterias) euplecta, n. sp.

Genus Hydrasterias Sladen.

Hydrasterias verrilli, n. sp.

## Family Brisingidæ Sars.

Genus Odinia Perrier.

Odinia pacifica, n. sp.

Brisinga Asbjørnsen.

Brisinga panopla, n. sp.

Brisinga alberti, n. sp.

Brisinga evermanni, n. sp.

Brisinga fragilis, n. sp.

There is proposed to replace *Goniodiscus*, which is untenable, the new generic name *Goniodiscides*, type *G. sebæ* (Müller and Troschel). See p. —.

One new family is established, Anseropodidæ, which equals the Palmipedinæ. The new name Goniodiscidinæ is proposed to replace Goniodiscinæ, on account of change of *Goniodiscus*.

Species for the first time recorded from the Hawaiian Group are *Astropecten polyacanthus*, *Goniodiscides sebæ*, *Astropecten velitaris*, *Linckia diplax*, *Valvaster striatus*.

One previously reported species was taken by the *Albatross*, *Mithrodia bradleyi* (sub nomine *clavigera*).

Species recorded from the Hawaiian Islands but not taken by the *Albatross* are listed below:

Luidia brevispina

Archaster typicus

Nidorellia armata

Culcita arenosa

Ophidiaster pusillus (?)

Linckia multifora

Nardoa ægyptiaca

Gymnasteria carinifera

Asterina granulosa

Heliaster multiradiata

From these lists it will be readily seen that previous to the expedition of 1902 only 11 starfishes (so far as I have been able to learn) were known from the region

and that the *Albatross* added nearly 5 times that number of species which are either new or constitute new records.

Although dredging in Hawaiian waters proved to be an undertaking which presented unusual difficulties, it is safe to say that no other area of similar extent has been so thoroughly developed or has yielded better results. With certain exceptions, the sea bottom, especially in the lesser depths, is very uneven and rough; during the progress of the work it frequently happened that when a haul was nearly successfully completed the gear would catch on some obstruction on the bottom, and a large part or the whole contents of the trawl would be lost. Off the north coast of Maui, however, and in certain restricted areas in the Pailolo Channel between Maui and Molokai good dredging was afforded, and it was in this general region that many of the novelties were taken.

*List of "Albatross" dredging stations at which starfishes were secured, with the species taken at each.*

Station.	Locality.	Depth.	Nature of bottom.	Species.
		<i>Fathoms.</i>		
3810	South coast of Oahu Island ....	211- 53	Fine coral sand .....	<i>Astropecten callistus.</i>
3813	.....do .....	264-183	Coral sand, lava specks, shells..	<i>Antheniaster epixanthus.</i>
3817	.....do .....	320	Coarse lava, coral sand, shells...	<i>Brisinga fragilis.</i>
3824	South coast of Molokai Island..	222-498	Coral rocks, broken shells.....	<i>Psilasteropsis cingulata, Benthaster eritimus, Brisinga fragilis.</i>
3828	.....do .....	319-281	Broken shells, gravel.....	<i>Odiinia pacifica, Brisinga panopla.</i>
3834	.....do .....	Shore.	Coral reef .....	<i>Ophidiaster loroli.</i>
3835	.....do .....	169-182	Fine brown sand, mud.....	<i>Astropecten callistus, Anseropoda insignis, Coscinasterias euplecta.</i>
3836	.....do .....	233-255	Brownish-gray mud and sand..	<i>Patagiaster nuttingi.</i>
3838	.....do .....	92-212	Fine grayish brown sand .....	<i>Calliderma spectabilis.</i>
3847	.....do .....	23- 24	Sand, stones.....	<i>Mithrodia bradleyi.</i>
3848	.....do .....	43- 78	Sand, gravel .....	<i>Linckia diplx.</i>
3849	.....do .....	73- 43	Coarse sand, broken shells, coral.	<i>Astropecten velitaris, Luidia magnifica, Pentaceros hawaiiensis.</i>
3850	.....do .....	43- 66	.....do .....	<i>Pentaceros hawaiiensis.</i>
3857	Pailolo Channel between Maui and Molokai islands and northeast approach.	127-128	Fine sand, yellow mud.....	<i>Astroceramus callimorphus.</i>
3859	.....do .....	133-140	Fine sand and mud .....	<i>Coscinasterias euplecta.</i>
3861	.....do .....	30- 52	Fine sand, small pebbles, coral.	<i>Luidia hystrix.</i>
3865	.....do .....	256-283	Fine volcanic sand, rocks.....	<i>Astropecten pusillulus, Psilaster attenuatus, Cheiraster inops, Tosia ceramoidea, Brisinga fragilis.</i>
3866	.....do .....	283-284	Gray mud, fine sand .....	<i>Psilaster attenuatus, Dipsacaster nesiototes.</i>
3867	Northeast approach to Pailolo Channel.	284-290	Fine sand and mud .....	<i>Psilaster attenuatus, Dipsacaster nesiototes, Pteraster reticulatus.</i>
3868	.....do .....	294-684	Fine gray sand, rocks .....	<i>Dipsacaster nesiototes, Cheiraster inops.</i>
3871	Auau Channel, between Maui and Lanai islands.	13- 43	Fine white sand.....	<i>Mithrodia bradleyi.</i>
3872	.....do .....	43- 32	Yellow sand, pebbles, coral...	<i>Pentaceros hawaiiensis, Leiaster callipeplus, Linckia diplx, Mithrodia bradleyi.</i>
3875	.....do .....	65- 34	Fine gray sand .....	<i>Leiaster callipeplus.</i>
3876	.....do .....	28- 43	Sand and gravel .....	<i>Luidia hystrix, Mithrodia bradleyi.</i>
3883	Pailolo Channel, between Maui and Molokai islands.	277-284	Globigerina ooze .....	<i>Psilaster attenuatus, Tosia ceramoidea.</i>
3884	.....do .....	284-290	Globigerina mud .....	<i>Psilaster attenuatus, Dipsacaster nesiototes.</i>
3885	.....do .....	136-148	Sand, pebbles .....	<i>Coscinasterias euplecta.</i>
3887	North coast of Molokai Island..	552-809	Globigerina mud .....	<i>Psilasteropsis cingulata.</i>
3892	.....do .....	328-414	Fine gray sand .....	<i>Zoroaster spinulosus, Brisinga fragilis.</i>
3908	South coast of Oahu Island ....	304-308	Fine white sand and mud .....	<i>Psilaster attenuatus, Dipsacaster nesiototes.</i>
3909	.....do .....	308-322	.....do .....	<i>Psilaster attenuatus.</i>
3910	.....do .....	311-337	Fine gray sand and mud.....	<i>Psilaster attenuatus, Dipsacaster nesiototes, Brisinga fragilis.</i>
3911	.....do .....	337-334	.....do .....	<i>Psilaster attenuatus, Hymenaster pentagonalis.</i>
3914	.....do .....	289-292	Gray sand and mud .....	<i>Tritonaster craspedotus, Hymenaster pentagonalis, Brisinga fragilis.</i>
3916	.....do .....	299-330	.....do .....	<i>Psilaster attenuatus.</i>
3917	.....do .....	330-294	.....do .....	<i>Do.</i>
3918	.....do .....	294-257	White sand, mud.....	<i>Astropecten pusillulus, Psilaster attenuatus, Tritonaster craspedotus.</i>
3919	.....do .....	257-220	Gray sand .....	<i>Tritonaster craspedotus, Patagiaster nuttingi, Pentagonaster amophilus.</i>
3920	.....do .....	280-265	Gray sand, broken shells.....	<i>Brisinga fragilis.</i>

List of "Albatross" dredging stations at which starfishes were secured, with the species taken at each—Cont'd.

Station.	Locality.	Depth.	Nature of bottom.	Species.
3935	Vicinity of Laysan Island	<i>Fathoms.</i> 57-79	White sand, broken shells, coralline.	Ctenophoraster hawaiiensis.
3937	do	130-148	White sand, small shells	Astropecten ctenophorus.
3938	do	148-63	White sand, broken shells	Calliderma spectabilis.
3940	do	59-70	do	Asterodiscus tuberculatus.
3957	do	220-173	Fine white sand	Astropecten callistus.
3960	do	10-19	Sand, shells, coral	Mithrodia bradleyi.
3975	Necker Island shoal	16-171	Coarse sand, coral, shells	Do.
3978	Vicinity of Bird Island	32-46	Coral, sand, foraminifera, rocks	Do.
3981	Vicinity of Kauai Island	636-414	Globigerina ooze	Cheiraster snyderi.
3982	do	233-40	Coarse brown coral sand, shells	Ophidiaster rhabdotus.
3987	do	65-60	Coarse coral sand, coral fragments.	Luidia hystrix.
3992	do	400-500	Fine gray sand, mud	Odinia pacifica, Brisinga panopla, Brisinga alberti, Brisinga sandwicensis.
3995	do	427-676	Fine gray sand, rocks	Psilasteropsis cingulata, Cheiraster snyderi, Pseudarchaster myobrachiatus.
3997	do	418-429	Fine gray sand, brown mud	Psilasteropsis cingulata, Cheiraster snyderi, Mediaster ornatus.
3998	do	235-228	Coarse brown coral sand, shells, rocks.	Cheiraster snyderi.
4007	do	508-557	Gray sand, foraminifera	Cheiraster snyderi, Zoroaster spinulosus.
4019	do	550-409	Gray sand, rocks, foraminifera	Mediaster ornatus.
4021	do	286-399	Coral sand, foraminifera	Do.
4022	do	399-374	Coral sand, rocks, foraminifera	Do.
4023	do	18-41	Gray sand, foraminifera, coral, rocks.	Ophidiaster squameus.
4024	do	24-43	Coarse coral sand, foraminifera	Mithrodia bradleyi.
4027	do	319	Fine gray sand, rocks	Psilasteropsis cingulata, Pseudarchaster myobrachiatus, Mediaster ornatus.
4028	do	444-478	Gray sand, globigerina	Astropecten velitaris, Luidia hystrix.
4031	Penguin Bank, off south coast Oahu Island.	27-28	Coral, fine coral sand, foraminifera.	Luidia hystrix.
4032	do	27-29	Fine coral sand, foraminifera	Luidia hystrix, Mithrodia bradleyi.
4034	do	28-14	do	Gilbertaster anacanthus, Brisinga fragilis.
4041	West coast Hawaii Island	382-253	Gray mud, foraminifera	Astropecten pusillulus, Astropecten callistus, Patagiaster nuttingi, Henricia pauperrima.
4044	do	233-198	Fine gray sand	Astropecten callistus, Coscinasterias euplecta.
4045	do	198-147	Coral sand, foraminifera	Mithrodia bradleyi.
4046	do	147-71	do	Astropecten pusillulus.
4048	do	374	Fine gray sand, rocks	Astropecten velitaris.
4055	Northeast coast Hawaii Island (Hilo Bay).	50-62	Fine gray sand, foraminifera	Astropecten velitaris.
4062	Northeast coast Hawaii Island.	83-113	Coral, volcanic sand, shells, foraminifera.	Mithrodia bradleyi, Coscinasterias euplecta.
4064	do	63-107	Volcanic sand, foraminifera, coral.	Coscinasterias euplecta.
4066	Aleunihana Channel, between Hawaii and Maui islands.	176-49	Rocky	Do.
4072	North coast of Maui island	56-59	Coarse coral sand, foraminifera	Pentaceros hawaiiensis.
4074	do	78-85	Coral sand, foraminifera	Calliderma spectabilis.
4075	do	49-57	Fine gray sand, foraminifera	Pentaceros hawaiiensis.
4077	do	99-106	Fine coral sand, foraminifera	Calliderma spectabilis, Ophidiaster sclerodermus.
4079	do	143-178	Gray sand, foraminifera	Astropecten callistus, Cheiraster horridus, Calliderma spectabilis, Coscinasterias euplecta.
4080	do	173-202	do	Astropecten callistus, Antheniaster epixanthus.
4081	do	202-220	do	Astropecten pusillulus, Pentagonaster ammophilus, Antheniaster epixanthus.
4082	do	220-238	Gray sand	Astropecten pusillulus, Patagiaster nuttingi, Pentagonaster ammophilus, Tosia ceramoidea, Antheniaster epixanthus.
4083	do	238-253	do	Astropecten pusillulus, Patagiaster nuttingi, Pentagonaster ammophilus.
4084	do	253-267	Fine gray sand	Astropecten pusillulus, Antheniaster epixanthus.
4085	do	267-283	Sand, shells	Astropecten pusillulus.
4086	do	283-308	do	Psilaster attenuatus.
4087	do	308-306	Fine gray sand	Do.
4088	do	306-297	do	Do.
4089	do	297-304	do	Do.
4090	do	304-308	do	Psilaster attenuatus, Hymenaster pentagonalis, Brisinga fragilis.
4091	do	308-306	do	Psilaster attenuatus, Brisinga fragilis.

List of "Albatross" dredging stations at which starfishes were secured, with the species taken at each—Cont'd.

Station.	Locality.	Depth.	Nature of bottom.	Species.
4095	NE. approach to Pailolo Channel between Maui and Molokai islands.	Fathoms. 290-286	Brown mud, fine sand, globigerina.	Psilaster attenuatus.
4096	do	272-286	Fine gray sand	Astropecten pusillulus, Psilaster attenuatus, Tosia ceramoidea, Brisinga fragilis.
4098	North coast of Maui Island	95-152	Coral sand, foraminifera, rocks.	Calliderma spectabilis.
4100	Pailolo Channel between Maui and Molokai islands.	130-151	Coarse sand, shells, foraminifera.	Calliaster pedicellaris, Ophidiaster squameus, Ophidiaster tenellus, Coscinasterias euptecta.
4101	do	143-122	do	Astropecten productus, Anseropoda insignis, Coscinasterias euptecta.
4102	do	122-132	do	Astropecten productus, Calliderma spectabilis.
4112	Kaiwi Channel between Molokai and Oahu islands.	447-433	Fine sand	Zoroaster spinulosus.
4114	Northwest coast of Oahu Island.	154-195	Coral sand, foraminifera	Astropecten callistus.
4115	do	195-241	do	Patagiaster nuttingi, Antheniaster epixanthus, Henricia robusta.
4116	do	241-282	do	Astropecten pusillulus.
4123	Southwest coast of Oahu Island.	352-357	Fine gray sand, mud	Psilasteropsis cingulata, Patagiaster nuttingi, Medilaster ornatus.
4128	Vicinity of Kauai Island	68- 90	Coarse brown coral sand, foraminifera.	Asterodiscus tuberculatus, Leiaster callipeplus, Ophidiaster triseriatus.
4131	do	309-257	Fine gray sand	Brisinga fragilis.
4132	do	257-312	Fine gray sand, mud	Nereidaster bowersi.
4134	do	324-225	Fine coral and volcanic sand	Do.
4139	do	512-339	Fine gray sand, rocks	Zoroaster spinulosus.
4141	do	437-632	Volcanic sand, foraminifera	Medilaster ornatus.
4146	Vicinity of Bird Island	23- 26	Coarse coral sand, foraminifera.	Mithrodia bradleyi.
4147	do	26	Coral, coralline	Mithrodia bradleyi (aberrant).
4149	do	33- 71	do	Leiaster callipeplus.
4151	do	800-313	Fine coral sand, foraminifera, stones.	Tosia micropelta.
4157	do	762-1000	White mud, foraminifera, rocks.	Asthenactis papyraceus.
4158	do	20- 30	Coral, coralline	Mithrodia bradleyi (aberrant).
4159	do	30- 31	Coarse coral sand, broken shells, foraminifera.	Mithrodia bradleyi.
4160	do	31- 39	Coral, coralline	Do.
4162	do	21- 24	Coral	Do.
4163	do	24- 40	do	Do.
4164	do	40- 56	Coral sand, pebbles, shells	Leiaster callipeplus, Mithrodia bradleyi.
4166	do	293-800	Coral sand, foraminifera, rocks.	Henricia pauperima, Brisinga fragilis.
4168	do	20- 21	Coral sand, foraminifera	Astropecten polyacanthus, Luidia hystrix.
4169	do	21- 22	Coral	Mithrodia bradleyi.
4170	do	26- 27	Coral sand, foraminifera	Do.
4177	Vicinity of Niihau Island	451-319	Gray sand, globigerina	Brisinga panopla, Brisinga alberti.
4178	do	319-373	Coral sand, rocks, pebbles	Brisinga panopla.
4186	East of Kauai Island	682-508	Gray sand, foraminifera	Evoplosoma forcipifera.

#### RELATIONSHIPS OF THE HAWAIIAN STARFISH FAUNA.

The Hawaiian Islands are of peculiar interest to a student of distribution, from the fact that they occupy such an isolated position and because they are surrounded on all sides by very deep water. Since the islands constitute a great mountain range rising from abyssmal depths, the sedentary and sluggish creatures that live at or near the top of this plateau occupy a position somewhat analogous to that of an alpine fauna on an equally isolated mountain range of some continent. Of course the great depths do not afford perfect barriers, since the larvæ of most marine invertebrates are swept about by ocean currents. With reference to the starfishes alone, it would appear that those forms which live at the shore or in very shallow water are slower to change under segregation than the species which dwell at a moderate or considerable depth. Or it may be that the latter is an older fauna, for it is true that every species is peculiar to the region. A number of shallow-water forms also are peculiar,

and I suspect with a good series of specimens for comparison nearly every littoral Hawaiian species would show small but constant differences.

The shore and shallow-water species of starfishes are all tropical forms, and those which are not peculiar to the group are derived from at least two distinct regions. We have first a group of species comprising very wide ranging forms, some of them extending from the Red Sea to China and Japan, and thence to Australia. In this group of ten species all but three occur in the Indian Ocean, and five range into the Red Sea. All extend at least to the eastern archipelago. Most of these forms are characteristic "South Sea" types. The other group comprises but five species and is derived from the coast of Mexico, Central America, and northern South America. The following tables detail these forms.

*Species common to the Hawaiian Islands and to the Eastern Archipelago, Indian Ocean, Japan, Polynesia or Australia.*

Species.	Locality.
<i>Astropecten polyacanthus</i> ...	Red Sea, Mauritius, Ceylon, Andaman Island, Port Jackson, Australia, New Zealand, China, Japan, Admiralty and Fiji Islands.
<i>Astropecten velitaris</i> .....	China Sea, Amboina, Northwest Australia, Admiralty Islands.
<i>Archaster typicus</i> .....	Eastern Archipelago, Pelew Island, Port Darwin, Port Essington, Cape Grenville, Port Denison, New Caledonia, Fiji, Samoa <sup>a</sup> , and Tonga islands, Nicobar Islands, Andaman Islands, Mergui.
<i>Goniodiscides sebæ</i> .....	Red Sea, Mauritius, Madagascar, Ceylon, Eastern Archipelago, Fiji Islands, New Guinea, Amboina.
<i>Culcita arenosa</i> <sup>b</sup> .....	Amboina.
<i>Linckia diplax</i> .....	Mauritius, Madagascar, Isle de Bourbon, Christmas Island, New Caledonia, Fiji and Tonga islands.
<i>Linckia multifora</i> <sup>b</sup> .....	Red Sea, Mozambique, Mauritius, Ceylon, Larentuka, Celebes, Amboina, New Caledonia, Fiji, and Samoa.
<i>Nardoa ægyptiaca</i> <sup>b</sup> .....	Red Sea, Mauritius, Bourbon, Samoa and Fiji islands.
<i>Gymnasteria carinifera</i> <sup>b</sup> .....	Red Sea, Mauritius, Ceylon, Eastern Archipelago, New Caledonia, Fiji Islands, Panama (?).
<i>Valvaster striatus</i> .....	Mauritius.

<sup>a</sup> Collected in Samoa in 1902 by D. S. Jordan and V. L. Kellogg.

<sup>b</sup> Specimens from the Hawaiian Islands not seen by the writer.

*Species common to the Hawaiian Islands and to the west coast of America*<sup>a</sup>.

Species.	Locality.
<i>Luidia brevispina</i> .....	Mazatlan, Mexico.
<i>Nidorellia armata</i> .....	West coast of Mexico, Central America, south to Ecuador and the Galapagos Islands.
<i>Gymnasteria carinifera</i> .....	Panama (?).
<i>Mithrodia bradleyi</i> .....	Lower California to Panama.
<i>Heliasaster multiradiata</i> .....	Lower California, Mexico, to Galapagos Islands.

Turning now to the species which are, so far as known, peculiar to the Hawaiian group, both shallow and deep water forms, we find that a number have related species in Japanese and Chinese waters, or in the Eastern Archipelago, as detailed in the following table:

<sup>a</sup> Only in the case of *Mithrodia bradleyi* have these species been directly verified. The Panama record of *Gymnasteria* is very doubtful. Ives records *Archaster typicus* from Mulege Bay, Lower California (Proc. Phil. Acad. Sci., 1889, p. 175). I have doubts concerning the correctness of the label.

*Species peculiar to the Hawaiian Islands, which have nearly related species in Japan, China, or in the Eastern Archipelago.*

Hawaiian species.	Corresponding species.	Locality.
<i>Luidia hystrix</i> .....	<i>Luidia aspera</i> .....	Samboagan and Tablas Island, Philippine group; north of Admiralty Island; 10 to 150 fathoms.
<i>Luidia magnifica</i> .....	<i>Luidia maculata</i> . [ <i>Luidia aspera</i> , also.]...	Japan, Manila, Coromandel, Java, Mergui, Ceylon, Mozambique.
<i>Calliderma spectabilis</i> .....	<i>Calliderma emma</i> .....	Japan.
<i>Calliaster pedicellaris</i> .....	<i>Calliaster childreni</i> <sup>a</sup> .....	Do.
<i>Asterodiscus tuberculatus</i> .....	<i>Asterodiscus elegans</i> .....	Philippine Islands; northeast China.
<i>Pentaceros hawaiiensis</i> .....	<i>Pentaceros orientalis</i> .....	China.
	<i>Pentaceros troschellii</i> .....	Billiton.
<i>Benthaster eritimus</i> .....	<i>Benthaster penicillatus</i> .....	North of New Guinea.
	<i>Benthaster wyville-thomsoni</i> .....	North Pacific, between Hawaii and Japan.

<sup>a</sup> Relationship not very close.

Still another set of forms appears to have been derived from the Indian Ocean, or at all events to show a marked resemblance to Indian species. Probably if a direct comparison of specimens could be made, this list would be considerably augmented.

*Species peculiar to the Hawaiian Islands which have nearly related species in the Indian Ocean.*

Hawaiian species.	Corresponding species.	Locality.
<i>Luidia magnifica</i> .....	<i>Luidia maculata</i> .....	Mozambique, Madras, Ceylon, Java, etc., littoral.
<i>Dipsacaster nesiotus</i> .....	<i>Dipsacaster sladeni</i> .....	Andaman Sea, 250 fathoms.
<i>Pseudarchaster jordani</i> .....	<i>Pseudarchaster mozaleus</i> .....	Indian Ocean, 200 fathoms.
<i>Mediaster ornatus</i> .....	<i>Mediaster florifer</i> (Alcock) .....	Andaman Sea, 130 to 250 fathoms.
<i>Antheniaster epixanthus</i> .....	<i>Antheniaster sarissa</i> .....	Do.
<i>Ophidiaster loriloli</i> .....	<i>Ophidiaster robillardii</i> .....	Mauritius, littoral.
<i>Ophidiaster squameus</i> .....	<i>Ophidiaster purpureus</i> (?) .....	Mauritius, Seychelles.
<i>Lelaster callipeplus</i> .....	<i>Lelaster glaber</i> .....	Querimba Island, littoral.
<i>Echinaster</i> sp. ....	<i>Echinaster sladeni</i> .....	Mauritius, littoral.

Considering these species in conjunction with those actually common to both areas, we are at once struck by the fact that the Hawaiian fauna bears more resemblance to that of the distant Indian region than it does to the fauna of America, notwithstanding that all the ocean currents which pass the Hawaiian Islands are coming from America and not from the west. Ocean currents are almost without doubt responsible for the gradual dispersal of echinoderm species, on account of the pelagic larvæ. It is interesting, therefore, to examine the ocean currents in connection with the apparent relationships of the Hawaiian starfish fauna.

During the southwest monsoon currents set northwest toward the equator in the Indian Ocean from the vicinity of Mauritius and the coast of Africa, thence pass east toward Ceylon, receiving an eastward current from the Gulf of Aden; or, turning more abruptly, flow eastward between the equator and 10° north latitude. These currents, passing the Bay of Bengal, meet a reverse current from the Strait of Malacca, but pass south of Sumatra through Sunda Strait, thence northeast between Borneo and Cochin China past the Philippines and Japan, where the stream is known as the Kuro Siwo. South of the Philippines and north of the Celebes a counter-equatorial current sets eastward in 5° north latitude, passing south of the Caroline and Marshall islands and north of the main, west-flowing, equatorial current. The countercurrent reaches the coast of Central America and is reflected

westward in latitude 10° north, along with a south-flowing current from the coast of North America. The currents which pass the Hawaiian Islands are consequently flowing westward and are derived from the counter-equatorial current and from North America. A branch of the Kuro Siwo sets southeastward from north latitude 35° to 40° toward the Hawaiian Islands, but apparently does not reach them.

During the southeast monsoon the currents are nearly reversed in the Indian Ocean, a stream (42 to 66 knots per 24 hours) setting directly eastward from the Seychelles, south latitude 5°, to the coast of Sumatra, but there is a west current in Sunda Strait and an eastward current along the north coast of Java.

Consequently if we think of the Indian Ocean as the center of dispersal for this fauna, about the only conceivable way in which the species could reach the Hawaiian Islands is by means of the counter equatorial, which is an insignificant stream when compared with the great west flowing equatorial. Yet all the currents setting from America have sufficed to bring only five species and these are by no means cleared of doubt.

Of course there is no a priori reason for considering the Indian the original fauna. The center of dispersal may have been farther eastward. In the case of *Valvaster striatus* it is a long cry from Mauritius to Hawaii, with no intermediate records. The similarity of such a rare type as the *Calliderma* of Japan with that of Hawaii is interesting. The genus, being an old one, is probably widespread, and a number of intermediate forms may remain to be discovered. If the Philippine group and a number of others along the path of the principal ocean currents were as thoroughly worked as the Hawaiian Islands, we would have a far more satisfactory basis for comparison. The *Challenger* made at most but 20 hauls in which starfish were captured, in the Eastern Archipelago, while in the limited area of the Hawaiian Islands the *Albatross* made 123. The results of the *Siboga* expedition may be looked forward to with interest.

Certain Hawaiian species show relationships with Atlantic forms, others with Australian and southern South American species. These are detailed in the following table:

*Species peculiar to the Hawaiian Islands and the apparently nearest relatives of those species (other than Indian Ocean and Eastern forms.)*

Hawaiian species.	Related species.	South Pacific.	Southern ocean.	Atlantic.
<i>Astropecten ctenophorus</i> ....	<i>Astropecten pectinatus</i> ....	Southeast of Australia; Port Phillip.	.....	.....
<i>Psilaster attenuatus</i> .....	<i>Psilaster acuminatus</i> .....	East of Australia; west of New Zealand.	.....	Simons Bay, Cape of Good Hope.
<i>Psilasteropsis cingulata</i> .....	<i>Psilasteropsis patagiatus</i> .....	.....	.....	Off Cape Verde Islands.
<i>Cheiraster inops</i> .....	<i>Cheiraster planeta</i> .....	West of South America (entrance to Straits of Magellan).	.....	.....
<i>Pseudarchaster myobranchius</i>	<i>Pseudarchaster tessellatus</i> ..	.....	.....	Simons Bay, Cape of Good Hope.
<i>Pseudarchaster jordani</i> .....	.....do.....	.....	.....	Do.
<i>Tosia ceramoidea</i> .....	<i>Tosia nitida</i> ; <i>Tosia compta</i> .....	.....	.....	West Indies.
<i>Anseropoda insignis</i> .....	<i>Anseropoda placenta</i> .....	.....	.....	Coast of Europe.
<i>Henricia robusta</i> .....	<i>Cribrella obesa</i> .....	.....	.....	Falkland Islands, Straits of Magellan.
<i>Henricia pauperrima</i> .....	<i>Cribrella compacta</i> .....	Off New Zealand .....	.....	.....
<i>Pteraster reticulatus</i> .....	<i>Pteraster semifreticulatus</i> ..	.....	Off Marion Island.	.....
<i>Hymenaster pentagonalis</i> ...	<i>Hymenaster carnosus</i> .....	West of South America	.....	.....

A few species stand alone, apparently. I have not been able to find any very close relatives.<sup>a</sup> Such are—

Astropecten pusillulus	Ophidiaster sclerodermus
Astropecten productus	Ophidiaster tenellus
Ctenophoraster hawaiiensis	Asthenactis papyraceus (related to
Gilbertaster anacanthus	Myxaster of Atlantic).
Evoplosoma forcipifera	

DESCRIPTION OF HAWAIIAN ASTEROIDEA.

SYNOPSIS OF THE FAMILIES.

- a. Marginal plates usually large and conspicuous in the adult, defining the contour of body. Papulae restricted to abactinal area (except in Linckiidae) circumscribed by the superomarginal plates. Ambulacral plates well spaced and broad. Mouth plates prominent. Actinostomal ring with adambulacral plates prominent. Pedicellariae when present spiniform, pectinate, valvate, or excavate.
- b. Abactinal skeleton composed of true columnar paxillae or paxilliform plates. Tegumentary developments usually spiniform. Primary apical plates usually not discernible. (See also *bb-c-d.*) Pedicellariae when present spiniform or pectinate, never bivalved or excavate.
- c. Superambulacral plates usually present; if absent, the marginal plates alternate and spiny. (In *dd.*)
  - d. At least the inferomarginal plates well developed; plates of the 2 marginal series opposite, not regularly alternate.
  - e. Fasciolar grooves between marginal plates usually well developed; paxillae typical; median radial paxillae smaller than those along sides of area. Anal aperture small or wanting (well developed in *Dipsacaster*).
  - f. Both series of marginal plates present.....ASTROPECTINIDÆ
  - ff. Superomarginal plates aborted, represented by a series of paxillae.....LUDIIDÆ
  - ee. Fasciolar grooves obsolete; median radial paxillae larger than those along sides of area; papulae not extending beyond middle of ray.....PSEUDARCHASTERIDÆ
  - dd. Plates of the 2 marginal series alternate, usually very spiny. An odd spiniferous interradial plate present in both marginal series in one genus (not Hawaiian). Papulae confined to limited area at base of ray, often to a special papular organ. Pedicellariae, when present, pectinate.....BENTHOPECTINIDÆ
- cc. Superambulacral plates absent. Medioradial series of paxillae conspicuously larger than the others. Marginal plates opposite. Spiniform pedicellariae often present. Superficially astropectinoid.....ARCHASTERIDÆ (restricted)
- bb. Abactinal skeleton not composed of true paxillae or paxilliform plates except in Mediasterinae, when bivalved or 2-jawed upright pedicellariae are present. Primary apical plates usually readily discernible. Tegumentary developments usually granuliform, although in the Mediasterinae the abactinal plates may have well-developed spinelets. In addition to granules the plates may bear specialized spines and tubercles. Pedicellariae valvate, excavate, or foraminat.
- c. Actinal interradial areas large.
  - d. Abactinal skeleton composed of polygonal or circular (occasionally stellate) plates which may or may not be united by separate internal radiating ossicles. The plates may bear a central tabulum, paxilliform in appearance, or may be simply flat and covered with granules or naked. In some genera the abactinal plates bear a central spine or tubercle, or several. Papulae usually confined to the abactinal radial areas. The plates may also be obscured by a tough skin which is superficially smooth (Leptogonasterinae) or covered with granules (Goniodiscidinæ).....GONIASTERIDÆ

<sup>a</sup>One great difficulty is a lack of figures and the poor descriptions of many East Indian forms.

- dd. Abactinal skeleton stellato-reticulate, the papulae usually numerous and in definite areas (except in *Asterodiscus*). Marginal plates sometimes superficially hidden. Abactinal plates often with large conical tubercles.....PENTACEROTIDÆ
- ddd. Abactinal skeleton tessellate; the plates often irregular and only partially contingent, the whole covered with a thick, leathery, skin. Flexible. Marginal plates inconspicuous,.....GYMNASTERIIDÆ
- cc. Actinal interradial areas small. Superambulacral plates usually present. Pedicellariæ, when present, excavate. Abactinal skeleton tessellate, arranged irregularly or in more or less regular longitudinal series, with intra- and often infra-marginal papulae. Rays usually slender, long, and subcylindrical.....LINCKIIDÆ
- aa. Marginal plates small and inconspicuous. Papulae not always confined to area circumscribed by the supermarginal plates, but often present between the marginal plates and on the actinal surface. Ambulacral plates may be crowded or not.
- b. Actinostomial ring with adambulacral plates prominent. Ambulacral plates not crowded. Abactinal skeleton composed of thin, close-set overlapping plates, or forming a more or less open reticulate network, either regular or irregular. In one family the abactinal plates are cruciform, with long paxillar spines supporting a supradorsal membrane. Pedicellariæ very rare, never pedunculate or excavate. Tube feet biserial.
- c. Mouth plates small, ambulacral groove narrow. Spines not conspicuously long and slender, or supporting a supradorsal membrane.
- d. Abactinal skeleton is formed of closely imbricating plates bearing small spines. Actinal skeleton formed of imbricating plates bearing a tuft or fan of spinelets. Marginal plates minute.
- e. Papulae distributed throughout the abactinal area. Abactinal plates thick, crescentiform, devoid of internal processes.....ASTERINIDÆ
- ee. Papulae confined to the radial regions. Abactinal plates in the median regions stellate. Abactinal plates thin, scale-like, with elongate internal prolongations. General form very thin and flat.....ANSEROPODIDÆ
- dd. Abactinal skeleton formed of plates disposed in longitudinal and transverse series, or in an irregular network, bearing spinelets; spinelets not disposed in a tuft or fan.
- e. Spinelets small, pointed, naked, or covered with a thin skin containing calcareous granulations. (*Valvaster* has large marginal bivalved pedicellariæ).....ECHINASTERIDÆ
- ee. Spines heavy, rigid, obtuse, covered with spiniform scales. Reticulation of the dorsum formed of triangles grouped in hexagons.....MITHRODIIDÆ
- cc. Mouth plates conspicuously large, plowshare-shaped, with conspicuous marginal and actinal spines. Marginal plates not visible. Abactinal plates cruciform as a rule, bearing a fascicle of rather long delicate spinelets united by a fold of the integument, or supporting a supradorsal membrane which roofs a specialized nidamental cavity.
- d. No supradorsal membrane. Spines united by a web. Rays more than 5.....MYXASTERIDÆ
- dd. A supradorsal membrane present.....PTERASTERIDÆ
- bb. Pedicellariæ pedunculate, either forcipiform or forcipiform (composed of 2 jaws and a basal piece). Skeletal plates bearing spines, often long and isolated, on or about which are usually grouped the pedicellariæ; or the pedicellariæ may be isolated. Marginal plates inconspicuous or aborted. Ambulacral plates often very crowded so that the tube-feet are disposed in 4 series. Abactinal skeleton formed of skeletal arches, independent or bound together by intermediate plates, forming a network with rectangular or very irregular meshes; rarely in mosaic. These skeletal arches correspond to every other, or to every third adambulacral, and are composed of pieces corresponding in the ventral, lateral, and dorsal regions of the body. Mouth plates very inconspicuous as a rule.
- c. Tube-feet quadriserial, at least at the base of rays. Actinostome with ambulacral plates prominent.
- d. More than 25 arms; interbrachial septa double.....HELIASTERIDÆ
- dd. Less than 15 arms (Hawaiian species, 5-armed); interbrachial septa single. .
- e. Adambulacral plates of 2 kinds, alternating, one projecting into the furrow, and separating with its spinelets the tube-feet; the other not prominent. They bear several spinelets in a transverse series. Skeleton regular, composed of imbricating plates...ZOROASTERIDÆ

- ee. Skeleton reticulated. Adambulacral plates not dimorphic. Adambulacral plates with 1 or 2 spines. Pedicellariæ usually numerous, either in wreaths about the spines, or scattered ..... ASTERIIDÆ
- cc. Tube-feet in 2 series throughout the ray. Actinostome with adambulacral plates prominent. Rays numerous, always more than 5, slender, sharply defined from disk, and armed with slender spines which are sheathed in membranous sacculi bearing many minute crossed (forcipiform), pedicellariæ. Abactinal skeleton confined to disk and base of ray, on the latter often disposed in independent spaced annular ridges or costæ.....BRISINGIDÆ

Order PHANEROZONIA Sladen, emended.

Family ASTROPECTINIDÆ Gray, 1840.

Astropectinidæ Gray, Synopsis of the Genera and Species of the Class Hypostoma (*Asterias* Linn.) <Ann. N. H., ser. 1, vol. VI, 1840, p. 180.

Key to the Hawaiian genera of Astropectinidæ.

- a. Both series of marginal plates well developed, forming a nearly vertical lateral face to ray. Superomarginal plates are not confined to the abactinal surface beyond basal fourth of ray, but form a part of the side wall of ray.
  - b. Inferomarginal plates separated from adambulacral plates throughout a portion of the ray by a series of small intermediate plates. Fasciolar grooves not well developed.
    - c. Marginal plates not tumid; intermediate plates extending nearly to tip of ray.....PSILASTER
    - cc. Marginal plates strongly tumid; intermediate plates extending only one-third length of ray.....PSILASTEROPSIS
  - bb. Inferomarginal plates touching adambulacrals; not separated throughout ray by a row of intermediate plates. Fasciolar grooves specialized, well developed.....ASTROPECTEN
- aa. The 2 series of marginal plates very unequal in size, forming an angulated margin to ray. Upper series much smaller, and usually confined to abactinal surface; lower series extending laterally beyond superior series.
  - b. Madreporic body not large and hidden by special paxillæ on its surface. Anal aperture very minute or wanting.
    - c. No well developed series of plates between inferomarginal and adambulacral series throughout ray (rudimentary at base of ray in *dd.*)
      - d. Size large. Rays long; a lateral series of flat, leaf-like spines bordering ray; superomarginal plates not conspicuously smaller beyond middle of ray.....ASTROPECTEN
      - dd. Size small. Oblique series of long seta-like spines on each *tumid* inferomarginal. Superomarginals very much reduced in size on outer half of ray.....TRITONASTER
    - cc. A well developed series of actinal intermediate plates between inferomarginals and adambulacrals. Inferomarginal plates broad and short, band-like; their spines many, appressed to ray.....CTENOPHORASTER
  - bb. Madreporic body large, hidden by paxillæ. Anal aperture present, conspicuous in *Dipsacaster*. Fasciolar grooves very deep.
    - c. Gonads disposed in a series along either side of abactinal integument of ray, extending beyond middle; papule distributed generally over the paxillar area.....DIPSACASTER
    - cc. Gonads confined to interradial regions, not extending far along rays; papule confined to the sides of paxillar area; absent from central portion of disk and rays .....PATAGIASTER

Genus ASTROPECTEN Schulze.

*Astropecten* C. F. Schulze, Betrachtung der versteinerten Seesterne u. ihrer Theile. Warschau u. Dresden, 1760.

Key to Hawaiian Species of *Astropecten*.

- a. Superomarginal plates with a single series of erect spines.
  - b. Spines stout, absent from second and sometimes third superomarginal. Spines of inferomarginals very prominent; not delicate, nor in an oblique comb.....*polyacanthus*

- bb. Superomarginal series of spines rather delicate, continuous throughout ray; not absent from second or third plate. Lateral spines slender, 4 in an oblique comb.....*denophorus*
- aa. Superomarginals devoid of a series of erect spines; sometimes a single spine on first superomarginal.
- b. Size small; no leaf-like lateral spines. Actinal interradiar areas small; superambulacral plates well developed.
- c. Size small; no leaf-like lateral spines.
- d. A single erect spine on first superomarginal plate; and a series of inconspicuous tubercles on plates of outer two-thirds of ray; the tubercles sometimes absent.....*velitaris*.
- dd. No spines whatever on superomarginal plates. Rays slender, flexible.....*pusillulus*
- cc. Size large; rays very long; a lateral series of large flat leaf-like spines. First 2 or 3 superomarginals with a conspicuous, erect, spinule.....*productus*
- bb. Actinal interradiar areas well-developed, paved with imbricating plates bearing spinelets in a paxilliform group; superambulacral plates present, but rudimentary in distal half of ray. No superomarginal spines.....*callistus*

***Astropecten polyacanthus* Müller and Troschel.**

Pl. I, fig. 1; pl. II, figs. 1, 1a, 1b.

*Astropecten polyacanthus* Müller and Troschel, System der Asteriden, 1842, p. 69, taf. v, fig. 3.

Rays 5.  $R=47$  mm.;  $r=10.5$  mm.  $R=4.3r$ . Breadth of ray at base, 12 mm.

Arms rigid, very gently tapering to a bluntly pointed extremity. Sides of arms rather high, perpendicular. Disk of medium size. Paxillar surface somewhat inflated. Interbranchial arcs acute but rounded.

Abactinal paxillar area is rather compact, the paxillæ being large and arranged in definite transverse rows, there being about 3 series to each superomarginal plate. Paxillæ are largest in the interradiar areas, midway between center and margin of disk, and also along median line of ray. Each paxilla consists of one or two central papilliform granules, surrounded by a radiating series of from 5 to 8 slightly longer ones, the whole crowning a rather long pedicel. On disk the largest paxillæ have upward to 5 central granules of unequal size, surrounded by 10-12 longer marginal ones, and occasionally one of the central granules is enlarged into a cylindrical pointed spinule. Less often one of the marginal spinelets is similarly enlarged (pl. II, fig. 1a), but the two never occur on a single paxilla.

Superomarginal plates, 22 in number from interradiar line to extremity of ray, are much higher than broad and do not encroach conspicuously upon paxillar area. They form a rectangular edge to the abactinal surface, and the first plate is raised slightly above the level of the others. Except the second plate, and on one ray the third, each bears a perpendicular, stout, pointed, conical spine situated on the abactinal face, slightly nearer aboral than adoral margin. The spine on first plate is longest and stoutest (as long as the longest spine of any inferomarginal, 4.5 mm.), the series decreasing in length toward tip of ray. The second superomarginal plate, which does not bear a spine, is smaller than either the first or third and is crowded by them. Plates are covered with small cylindrical papilliform spinelets, which become stouter and squamiform toward base of spines. Wide fasciolar grooves between the plates (i. e., between the specialized, elevated, exposed surfaces).

The inferomarginals, which are broader than high, correspond to superomarginals in number and do not extend beyond them laterally. Each plate bears a transverse series of 3 stout and relatively long, tapering, slightly flattened, sharp-pointed spines, the upper longest; to which is added a fourth spinule at inner end of series on third to seventh plates. First 2 plates usually have only 2 shorter, widely spaced spines. Plates are covered with slender papilliform spinelets in the fasciolar grooves and at upper end, these becoming longer, strongly flattened, and bluntly rounded or chisel-shaped at tip, in the vicinity of spines, and on actinal surface generally.

Adambulacral armature is in 3 series. The furrow series consists of 3 long, stout spinelets, the median longest, blunt, somewhat triangular in cross section at its base, the lateral spinelets flattened and truncate. Second series consists of 2 stouter, much flattened, truncate spinelets, the one nearest aboral margin being the larger. Third series consists of 3 blunt, flattened spinelets somewhat smaller than the furrow series, the median being usually slightly the longest of the 3 and most flattened. There is an odd spine, smaller and pointed, situated behind the third series. In all there are usually 9 spines on each adambulacral plate.

Actinal interradial areas are much reduced and are paved each with 4 small roundish plates, which bear spinelets very similar to those covering adjacent inferomarginals.

Mouth plates are prominent, the armature, unfortunately, having been largely destroyed. The marginal spinelets are rather slender, slightly flattened, the innermost 2 or 3 of each plate forming at each mouth angle a horizontal fan of 4 to 6 teeth, of which the median are longest.

Tube feet large, with an incipient conical sucker at end, easily distinguishable from the rest of the foot.

Madreporic body is not visible superficially; hidden by the paxillæ.

Color in life: Paxillar area of distal half of arms vinaceous cinnamon; remainder of arms, and disk, fawn color. The dorsal integument, largely hidden by the regular and ornate paxillæ, is bright vermilion, the color being visible between the spinelets of the paxillæ. Spines of superomarginal plates, orange buff. Marginal plates, inferomarginal spines, and entire actinal surface, light buff pink. Color in alcohol bleached yellowish.

Locality: Station 4168, vicinity of Bird Island, 20 fathoms, coral, shells, and foraminifera. Bottom rough.

Only a single specimen of this handsome species was secured, and that unfortunately, is not perfect. I have felt some misgivings in referring it to *polyacanthus*, having been obliged to depend wholly on the original description. In proportions the specimen agrees most nearly with Müller and Troschel's description of *armatus* (System der Asteriden, p. 71), from Japan, which Sladen and others consider the same as *polyacanthus*, the type of which came from the Red Sea. The descriptions of these two species certainly differ in many points, and presumably the types do also, but in view of the opinion of Sladen and Perrier I have accepted the present name. I have given a full description, with figures, that there may be no mistaking the particular form referred to, whether the name be correct or not.

This species may be readily distinguished from others of the genus inhabiting Hawaiian waters by the row of erect superomarginal spines, the second and sometimes the third superomarginal lacking the spine; and by the stout spines of the inferomarginals, arranged on each plate in a series of three or four.

*Astropecten polyacanthus* has a wide distribution, extending from the Red Sea to Zanzibar, Ceylon, Hongkong, the coasts of China and Japan (Kobe, Yokohama), New Holland, Admiralty Islands, Fiji Islands, and Port Jackson, Australia. It is a shallow-water species exclusively, ranging from 2 to 50 fathoms, the usual depths at which it is found being 25 fathoms and under. The station at Bird Island is the most eastern record for the Pacific, very materially extending the known range of the species.

#### *Astropecten velitaris* Von Martens.

Pl. I, fig. 2; pl. II, figs. 2, 2a.

*Astropecten velitaris* Von Martens, Archiv f. Naturgesch., Berlin, jahrg. XXXI, bd. I, 1865, p. 360.

Rays 5.  $R=25.5$  mm.;  $r=7$  mm.  $R=3.6r$ . Breadth of ray at base, 8.5 mm.

Rays stout, very gently tapering to a blunt point. Interbrachial arcs open, forming a nearly right angle. Disk of medium size. Epiproctal prominence present. Disk slightly swollen.

Abactinal paxillar area compact, the paxillæ being arranged in transverse rows on the rays. Paxillæ consist of 1 or 2 central rounded clavate spinelets or elongated granules, surrounded by 8 to 11 similar ones, arranged in a rosette. Papilliform granules of the peripheral series are not always equal in size on the same paxilla, 2 or more being slenderer than the others. Paxillæ become much smaller at the end of rays.

Superomarginal plates, 17 in number from interradial line to tip of ray, are massive, about as high as broad, and encroach conspicuously upon abactinal paxillar area, forming a rounded margin to ray. The first plate bears a short, erect, rather slender, tapering, sharp-pointed spinule. Plates are covered with small papilliform granular spinelets, capillary in the fasciolar grooves, becoming squamiform on the exposed surface of plates. The fifth to seventeenth plates each bear a short stubby conical tubercle or enlarged granule on the angle between the lateral and dorsal superficies of the plate. The second to fourth plates, inclusive, do not bear these.

Inferomarginal plates form an arched bevel to actinal surface and extend very slightly beyond superomarginals, laterally. Each plate bears an oblique row of 2 sharp, slender, often slightly curved,

somewhat flattened spines, placed at upper end of plate. The upper spine is longer, and the 2 form a double, lateral, longitudinal series to ray. Below the innermost spine along aboral margin of plate are 3 spinules, the upper placed close to the lower lateral spine and the others widely spaced. The first plate lacks the 2 lateral spines, but possesses the 3 lower spinules. A short, odd spinule is often found immediately adoral to the lower lateral spine. The 2 spines and 3 spinules of each plate form a single transverse series. Plates are covered with small, flattened papilliform granules or spinelets, which by reason of their standing out from the plates do not give the impression of being squamiform.

Adambulacral armature consists of a furrow series of 3 long, slender, somewhat flattened spinelets, of which the median is much the longest; and on actinal surface, a group of 3 flattened, round-tipped or truncate spinelets, placed in a more or less regular longitudinal series. Of the latter, 2 are slender, while the third, near aboral margin, is larger and flatter. Near base of ray the actinal group may have as many as 6 spinelets, placed usually in 3 rows of 2 each (due to a shortening of the plate), but one spinelet is always conspicuously the largest.

Armature of the ovoid mouth plates consists of a marginal series of 10 or 11 slender, obtuse spinelets, which increase in length toward inner angle, where 2 are enlarged (the innermost longest), forming, with those of the companion plate, a horizontal fan-shaped series of slightly flattened blunt teeth. The marginal series extends a little more than halfway to outer end of plate, and its spinelets usually stand out over furrow. The superficial series consists of about 10 similar, usually blunter, spinelets, arranged along suture margin, so that a conspicuous, unarmed furrow is left on inner half of plate, between it and the marginal series, and on the outer half between superficial series and first adambulacral plate.

Actinal interradial areas small, there being but 4 small intermediate plates bearing a group of delicate and slender spinelets.

Madreporic body obscured by paxillæ.

Color in life: abactinal paxillar area reddish sepia, becoming burnt sienna toward tips of rays. Marginal plates pale yellowish-brown edged with darker; lateral spines whitish. Actinal surface whitish.

Young: From the presence of an epiproctal elevation on all the specimens I seriously doubt their being fully adult. There is a small example with a major radius of 9 mm., which lacks entirely the spine on each first superomarginal plate, and also the tubercle on the outer superomarginals. The lateral spines of the inferomarginals are small, and there is no trace of the 3 aboral spinules. A very prominent epiproctal cone is present.

Variations: A larger specimen ( $R=21$  mm.) from Penguin Bank has much less massive marginal plates than the example from Hilo Bay used in the above diagnosis, but the armature is essentially the same.

Locality: Station 3849, between Molokai and Lanai Islands, 73-43 fathoms, coarse sand, broken shell, coral; 1 specimen. Station 4031, Penguin Bank, south coast of Oahu Island, 27 fathoms, fine coral sand, coral, and foraminifera; 2 specimens. Station 4055, Hilo Bay, Hawaii, 50 fathoms, fine gray sand and foraminifera; 1 specimen.

This form is readily distinguished from the preceding by the single erect spine on the first superomarginal plate. The species is as near to *velitaris* as to any described form, although the small tubercles on the outer superomarginals are not typical.

#### ***Astropecten ctenophorus*, new species.**

Pl. I, figs. 4, 5; pl. II, figs. 3, 3a-d.

There is a small *Astropecten*, dredged in 130 fathoms, near Laysan Island, which belongs near *Astropecten pectinatus* Sladen, from Australian waters (Port Jackson, off the entrance to Port Philip, East Monceur Island, Bass Strait, in 6 to 40 fathoms). It differs from this species, however, in several well-marked characters, which can not be accounted for because of a difference in size. I would hardly feel justified in bestowing a name upon such a small specimen, did it not belong to a small section of the genus—that division characterized by having a small spine on every superomarginal, and a lateral, oblique comb of 3 to 5 spines on each inferomarginal.

Rays 5.  $R=12$  mm.;  $r=4$  mm.  $R=3$  r. Breadth of ray at base, 4.5 mm.

Rays are fairly broad at base, tapering continuously to extremity, which is sharp. Interbrachial arcs subacute, very slightly rounded. Abactinal paxillar area plane; no epiproctal protuberance.

Paxillæ of abactinal surface are large and uniform on arms, but of various sizes on disk, where the largest paxillæ occur. Each consists of a very short rounded basal portion, surmounted by a group of 6-16 relatively long, slender spinelets, which radiate from the pedicel top. Of these 1 to 3 or 4 are usually central, the remainder forming an irregular series about them. Usually the spinelets form a widely radiating group, the central ones being stouter than those about the periphery. Very small paxillæ with only 1 to 4 or 5 spinelets are scattered over disk; and at end of the ray these predominate. Papulæ large, confined to border of paxillar area, there being none on median radial areas of ray, or on central portion of disk.

Superomarginal plates, which are 14 in number from median interradiial line to extremity of ray, are about as high as broad in the middle of the ray, higher than broad at the base, and broader than high at the extremity. The plates are set very slightly oblique in relation to the long axis of ray, and each when viewed from above is about as long as broad, except in interbrachial arc, where the plates are narrower. They form a nearly right-angled margin to ray. Each bears on the edge formed by the lateral and dorsal superficies a small cylindrical spinule, placed nearer aboral margin than center. Those on first 2 superomarginals are not larger than others. The plates are beset with rather widely spaced, slender, papilliform spinelets.

Inferomarginal plates are broader than high, and do not extend laterally beyond the superior series. Each plate bears an oblique comb of 3 or 4 lateral, delicate, cylindrical, tapering spines, the line of the base forming an angle of about 45° with the transverse axis of the plate and tending from the upper adoral corner downward and aborally. The adoral is the smallest, and most laterally situated. The third from this is the longest; the second is intermediate in size, and the fourth is usually slightly longer than second and nearly as long as third, but on outer half of ray may be much shorter than either second or third. Basalmost inferomarginal bears but 2 or 3 spines. A small spinule is sometimes present on the aboral side of the plate a little distance from the comb. Surface of inferomarginal plates is covered with delicate, slender, papilliform, subcapillary spinelets, which show no tendency to become squamiform.

Armature of adambulacral plates consists of (1) a furrow series of 3 spinelets and (2) a group of 8 or 10 actinal spinelets arranged in either 2 or 3 irregular longitudinal series. Furrow spinelets long and slender, bluntly pointed, the median spinelet longest, and at the base somewhat flattened (in axis crosswise to furrow). They usually stand perpendicularly to plate. On outer half of ray the first series of the actinal group consists of 4 long, very slender cylindrical spinelets, standing upright. The one at the aboral end of series stands on the furrow margin, aborad to lateral spinelet of furrow series, so that the latter appears often to consist of 4 spinelets. On these plates the second actinal series also consists of 4 spinelets, shorter and slenderer, which, by reason of the obliquity of the plate, extend further aborally than the furrow series. Toward base of ray there are usually 3 series of actinal spinelets, very irregular in arrangement, with 3 spinelets to each series, and an odd spinelet between the furrow and first actinal series. The aboral spinelet of the latter is always situated in line with furrow series. One or 2 small spinelets may be added at outer end of plate.

Actinal intermediate plates, 18 in number to each interradiial area, show a tendency to encroach upon base of ray. Actinal interradiial areas rather pronounced for an *Astropecten*. Each plate is covered with 5 or 6 very delicate subcapillary spinelets, similar to but smaller than those of actinal surface of adambulacrals.

Mouth plates of moderate size. Their whole surface is covered with small slender cylindrical spinelets disposed in three series—a marginal, a superficial, and an intermediate (pl. II, fig. 3d). The innermost spine of the marginal series is much enlarged, forming with its companion 2 stout, blunt, cylindrical teeth at each mouth angle.

Madreporic body small, with very coarse ridges; situated close to margin.

Color in alcohol, ashy white.

Locality: Station 3937, vicinity of Laysan Island, 130-148 fathoms, white sand and small shells; bottom temp. 63°; 1 specimen, type no. 21143, U. S. National Museum.

This species differs from its nearest relative, *A. pectinatus*, in the following respects: Character of abactinal paxillæ, those of *pectinatus* having more numerous, shorter spinelets; disposition of papulæ; character of spines on inferomarginals; character of adambulacral armature, that of *pectinatus* being

arranged in 3 distinct series of 3 each, the spinelets of the 2 actinal series being flat, rather short, with expanded, roundly truncate tips; armature of mouth plates; size of actinal interradiar areas, and number of actinal intermediate plates, these being less numerous in *pectinatus*. The present species may be readily distinguished from other known Hawaiian forms by the presence of an oblique comb of 3 or 4 comparatively short, appressed, close-set spines on the sides of the inferomarginal plates, and by the presence of a small, erect spinule on all the superomarginals.

***Astropecten pusillulus*, new species.**

Pl. I, fig. 3; pl. II, figs. 4, 4a-b.

Rays 5. R=33 mm.; r=6.5 mm. R=5r. Breadth of ray at base (between first and second superomarginals) 6.5 mm.

Rays long, slender, delicate, flexible; tapering from a narrow base to a blunt point. In many specimens the outer half of ray has the sides subparallel, then abruptly tapering at the extremity. Disk small; general form depressed, but abactinal paxillar area inflated both on disk and rays. A slight epiproctal elevation usually present. Actinal surface slightly convex. Interbrachial arcs subacute.

Abactinal integument rather thin and the paxillar area uniform and compact. Paxillæ not arranged in definite order. Each arm is marked off from the disk by a shallow furrow in the interradius, which broadens toward the center of the disk, and insensibly grades into its fellows of the 2 neighboring interradii. In this way a stellate area is often formed in center of disk, due to the greater inflation of radial areas, and characterized by a much more compact arrangement of paxillæ. Paxillæ decrease in size toward median radial line, extremity of ray, and center of disk, the largest being found, therefore, in the interradii, and the lateral portions of the base of rays. Each paxilla consists of a columnar ossicle, flaring at the base, surmounted by a single central spinelet which is surrounded by a peripheral row of 6 to 8 club-shaped, papilliform spinelets, each invested with a rather thick layer of membrane. These spinelets are a trifle longer than the basal portion of the paxilla, and they do not usually radiate a great deal. Smaller paxillæ on the arms have 4, 5, or 6 spinelets in the marginal series, and lack the central spinelet. The calcareous portion of these spinelets is slender and cylindrical, the membranous investment producing the clavate appearance.

Superomarginal plates, 31 in number from interradiar line to extremity of ray, are about as broad as long, except on the outer third of ray, where their length exceeds the breadth. First 3 plates are higher than long. They form a conspicuous, slightly rounded bevel to margin of paxillar area, tending to become flattened on the outer half of ray, but almost perpendicular in the interbrachial arcs. For a considerable portion of the outer two-thirds of ray they are nearly uniform in size. All are uniformly covered with papilliform granules or spinelets, much larger than those of paxillæ, clavate or sometimes slightly squamiform in shape, each spinelet invested with a pulpy sheath. No spines on superomarginals. Furrows between plates deep, forming well-developed fasciolar grooves.

Inferomarginals correspond in number to superomarginals, and are placed exactly opposite to them. They are much wider than long, forming an even, rounded bevel to sides of actinal surface. They extend but slightly beyond superior series, are armed with an oblique row of 2, or in largest specimens, 3, short, stout, tapering, sharp-pointed spines, placed near the upper or lateral margin. On the outer half of ray the series is rather nearer the aboral than the adoral margin. When there are 3 spines, the 2 outer, or upper, are of about equal length, and considerably longer than the lowest; when only 2 are present, the third to sixth inferomarginals usually have an extra spinule added to the inner end of the series. On first inferomarginal plate, the spines are more reduced in size, and 2 extra spines are added, while 1 is added to the series on the second and third plates. General surface of plates covered with papilliform "barley-corn" spinelets, similar to but larger than those covering superomarginals.

Adambulacral plates with convex margin to furrow. Armature is arranged in 3 series on inner part of ray, but becomes reduced to 2 on the outer half. Inner or furrow series consists of 3 spinelets which are rather short, the middle one larger than the laterals, and slightly tapering, being flattened to produce a blunt-ended blade with the edge toward furrow. The 2 lateral spinelets are slender and tapering. The 2 spinelets of the second series are associated with the furrow series on the proximal plates in large specimens. Second and third (actinal) series consist of 2 tapering and pointed spinelets

each, but toward the middle of ray the outer series becomes reduced in size, finally to an odd spine which persists on a few plates, and eventually disappears at about the middle of ray. Second series persists to tip. In the majority of specimens, on the inner part of ray the actinal spines are grouped into a very definite pedicellarian apparatus, conical in shape. These may be confined to plates of the basal third of ray, or may extend to the limit of the outer actinal series. Rarely on the outer portion of ray a few of the plates have the furrow and second series loosely grouped into a similar apparatus. On innermost plates bearing the actinal pedicellariae an odd actinal spinelet is present. Sometimes there are 5 or 6 actinal spinelets instead of 4.

Actinal interradial area almost absent. There are about 4 small intermediate plates, each of which bears a 4-valved pedicellaria, similar to, but slightly smaller than those of the adambulacrals.

Mouth plates rather small, elongate, and narrow, with relatively short armature consisting of a superficial series of 10 stout, short, tapering, pointed spinelets, arranged along the edge of the median suture; subequal, except the 2 or 3 outermost, which are smaller, and the innermost, which forms with that of the adjacent plate a pair of longer, tapering, pointed teeth, directed toward actinostome. The spinelets of the superficial series are often blunt. A marginal series of 5 to 8 shorter, pointed spinelets is placed at a higher level, facing the ambulacral furrow. These are either directed outward into furrow, or are appressed against the base of the innermost spinelets of the superficial series. Considerable variation exists among the specimens in regard to the details of armature, such as the number and shape of spinelets, as well as their relative sizes.

Madreporic body small, partially obscured by paxillae, and situated a little less than its own diameter distant from the margin. Striations coarse and rather few in number.

Color in life: Paxillar area dull olive brown, the marginal plates dull pinkish yellow, or straw color; actinal surface very pale straw yellow.

Young: The smallest specimen taken (station 4181) has  $R=7$  mm., and  $r=2.25$  mm., and besides having relatively shorter arms than the larger examples, differs in details of ornamentation. The paxillae lack the central granule, there being about 4 or 5 granules spaced around the margin of pedicel. Inferomarginals have but 2 spines. The furrow series of adambulacrals is relatively more conspicuous than in the adult, and the central spinelet is less different from the 2 lateral ones. On first adambulacral plate there are 4 actinal spinelets, 3 of which form a pedicellaria. On second and third plates there are 3 spinelets each, and beyond this point, only 2. A very prominent epiproctal elevation is present. All stages between this and the adult are represented in the collection.

Locality: Type (no. 21144, U. S. National Museum) from station 4116, northwest coast of Oahu Island, 241-282 fathoms, coral sand and foraminifera; bottom temperature 48.8°. *Astropecten pusillulus* was taken in greatest abundance off the north coast of Maui, in from 220 to 253 fathoms, on gray sand. Nearly 650 specimens have been examined. The following is a complete list of the stations:

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
3865	Northeast approach to Pailolo channel between Maui and Molokai islands.	256-283	Fine volcanic sand, and rocks.
3918	South coast of Oahu Island	294-257	White sand and mud.
4044	West coast of Hawaii Island	233-198	Fine gray sand.
4045	do.	199-147	Coral sand foraminifera.
4048	do.	374	Fine gray sand, rocks.
4082	North coast of Maui Island	220-238	Gray sand.
4083	do.	238-253	Do.
4084	do.	253-267	Fine sand.
4085	do.	267-283	Sand, shells.
4096	Northeast approach to Pailolo channel	272-286	Fine gray sand.
4116	Northwest coast of Oahu Island	241-282	Coral sand, foraminifera.
4181?	Vicinity Kauai Island?	811-671?	Probably an error for 4081.
3472	South coast of Oahu Island	295	Fine white sand. (Cruise of 1891.)

The present species is characterized by its small size, slender rays, unarmed superomarginals, and the character of its paxillae and adambulacral armature. It appears to be very distinct from any described form.

*Astropecten productus*, new species.

Pl. II, figs. 5, 5a-5f; pl. IV, figs. 1-3.

Rays 5.  $R=183$  mm.;  $r=19.5$  mm.  $R=9.3$  r. Breadth of ray at base, opposite first superomarginal, 23 mm.; opposite fifth superomarginal, 25 mm. Width of ray 1 centimeter from tip, 10 mm. Height of ray at base, 10 mm.

Size large; rays long, rather slender and flat; disk relatively very small, the minor radius being less than the width of ray at base. General form depressed, flat. The rays taper very gently to a blunt extremity, and on the outer portion the sides appear almost parallel when viewed from above. Most of the rays are constricted at the base, so that the widest portion is at the fourth or fifth superomarginal plate. Interbrachial arcs are very acute. Abactinal surface plane; actinal surface convex, with broadly beveled margins.

Abactinal paxillar area is uniform and moderately compact on disk, but often rather open on the rays, since the spinelets of the small paxillæ frequently do not radiate to any extent. In specimens where the paxillæ are all expanded like flowers the general appearance is compact. Paxillæ are arranged in rather regular transverse rows at base of ray, except along the medioradial line. On outer half of ray these regular series are confined to a narrow border adjacent to the superomarginal plates. No regularity on disk. Each paxilla is surrounded by about 6 papulæ in a hexagonal series. The latter are absent from the medioradial line of ray. The paxillæ are largest on disk and at either side of medioradial areas. Each consists of a short cylindrical ossicle, flaring at the base, flat-topped, sometimes elliptical in section, surmounted by a central group of 7 or 8 slender spinelets, which are surrounded by a marginal row, more or less irregular, of from 12 to 16. On outer third of arm paxillæ are smaller, but the spinelets decrease only a trifle in number, the average being about 10 in marginal series and 4 or 5 in the central group. Scattered among these are still smaller paxillæ with 7 or 8 marginal spinelets and only 2 or 3 central ones. The spinelets are two-thirds as long as the supporting pedicel.

Superomarginal plates, about 90 to 92 in number from interradial line to extremity of ray, form a well defined, conspicuous, and uniform border to paxillar area. Except for the first 8 or 10 plates they lie entirely on the abactinal surface. The inferomarginals with their prominent spines form the edge of the ray as they project laterally beyond the superomarginals. In the interbrachial arcs the superomarginals for a short distance form a rounded bevel to the margin. They decrease very gradually in size toward the extremity of ray. The length equals about two-thirds the width. The plates are set obliquely, as to their transverse vertical axis, so that their aboral margin slightly overlaps the adoral of the succeeding plate. The aboral margin is curved, and is armed with a series of 4 (varying to 3, 5, or 6) short, stumpy, sharp, squamiform spinules, evidently modifications of the squamiform spinelets which cover remainder of exposed surface of plate. In the fasciolar grooves between plates the papilliform spinelets are slender, becoming gradually thicker, then flatter, toward the aboral margin. In dried specimens, after the membrane has disappeared, this graduation in size is even more evident, but the spinelets no longer appear papilliform, owing to the absence of an organic investment. On the first 2 superomarginals one of the spinules is enlarged, becoming conical and erect, but it is not conspicuous. Terminal plate fairly conspicuous, bifurcate at base, blunt, grooved on lower surface.

Inferomarginals, which correspond in number to superomarginals, are very wide in proportion to length (3.5 to 4.5 : 1) and form a broad even bevel to the margin of the actinal area. The upper end of each plate extends beyond superomarginals, is strongly tumid, and the series forms the margin of the ray. The inner or lower end of the inferomarginals slightly overlaps the outer end of the adambulacral plates. Armature of each inferomarginal plate consists of numerous spines of various sizes, which may be roughly divided into two series: (1) Along the aboral edge of each plate, extending from the extreme inner to the upper or abactinal tumid end, is a row of from 10 to 14 spines and spinules. The uppermost spine surmounts a slight boss on the abactinal tumid end of the plate and is large, flat, leaf-like, lanceolate-acute, or oblanceolate-acuminate, about 6 to 7 mm. in length, by 1.5 to 2 mm. broad. These blade-like spines are very conspicuous, and form a regular series along the side of the ray, resting with their flat side upward. Following these, on the very edge of the ray, are 2 sharp, slender, slightly flattened spines, the upper usually the longer, being about two-thirds to seven-eighths as long as the heavy lateral spine. Occasionally there are 3 in the

group. In a series below these, extending to the lower (inner) end of plate, are from 7 to 11 spines and spinules similar to the 2 just described except in size. Of these the 2 or 3 following the lateral spines are short, and then come 5 conspicuous, slender, tapering, sharp-pointed spines, increasing in length toward the innermost, which is about 5 mm. long, and is situated at the inner end of plate. Between any two of them there is usually a short spinule, about one-fourth to one-third their length. Occasionally there is an odd spine, set out of line with the above series, toward the median line of the plate. (2) The second series of spines forms a semicircular row about the adoral side of the large flat spine, and the lower (inner) end of the series abuts against the regular aboral series, just below the 2 slender marginal spines which accompany the big one. Two spines of this series are placed in an oblique row between the flat spine and the superomarginal plates. Immediately adoral to the large spine are 1 or 2 short spinules, and then between these and the regular aboral series 5 to 7 slender, very sharp, tapering spines, forming a graduated series which merges into the regular transverse series as described above. All are closely appressed to the base of the flat spine. The abactinal surface of each inferomarginal is covered with papilliform spinelets similar to those investing the superomarginals, while the actinal surface is crowded with stouter, clavate, papilliform spinelets, each sheathed with a thick, pulpy investment. They become slightly larger toward the lower end of the plate.

Adambulacral plates numerous, separated by wide sutures and with an angular margin to furrow. Armature composed as follows: (1) A furrow series of 3 long, slightly tapering, round-tipped or truncate-spines, the median of which is longest and stoutest; all are compressed, especially the median, which is saber-like; on the basal portion of the ray usually stand 2 of the actinal spines, one at either end of the furrow series, these, however, shorter and placed behind the lateral furrow spines. (2) Spines of the actinal surface of plate in 3 irregular longitudinal rows of 3 (or 2) each. The median spine of each series is usually flattened and roundly truncate at the tip, the 2 laterals tapering and much smaller. Behind the 3 series of actinal spines are 3 to 6 smaller spinules or spinelets, irregularly placed, on the outer end of the plate. The actinal spines, especially the smaller, are invested with a sheath of pulpy membrane, which greatly increases their thickness. On a dried specimen these same spines are slender, cylindrical or slightly compressed, and exceedingly fragile.

Actinal intermediate plates, few in number (8 to 10), are very small and confined to the inconspicuous interradiar area, which does not extend beyond first inferomarginal. The interradiar area forms a triangle the sides of which do not exceed 5 mm. The plates are covered with spinelets similar to those of the inferomarginals.

Mouth plates are narrow and not prominent actinally. Armature consists of a marginal series of stout, flattened, blunt spines, 4 of which are arranged in a graduated series on the inner end of the plate, the 2 nearest median suture being largest, and the combined series of the 2 companion plates form a horizontal fan-shaped series. The marginal series, reduced in size, is continued for a short distance along the edge of the plate adjacent to first adambulacral. On actinal surface a superficial series of blunt or pointed, flattened spines extends from end to end of plate along the median sutural margin. Between this and marginal series is an intermediate row of 8 or 10 spines which extend about two-thirds the distance to outer end of plate and are graduated in length, the longest being innermost.

Madreporic body of medium size, situated nearly midway between the margin and center of disk. Striations not conspicuous.

Color in life from immature specimens: Abactinal paxillar area deep vinaceous cinnamon (except paxillae crowns, which are lighter pinkish buff), shading to cinnamon at tips of arms. Marginal plates buff; large flat marginal spines rose pink. Actinal surface whitish. Color in alcohol dull light brown.

Variations: The chief variations in this species are in minor details of spinulation of the actinal surface of inferomarginals and the relative length of the arms. All the arms of a single specimen are not always exactly the same length. If the minor radius be taken as a unit, the rays of the type are 9.5, 9.3, 9.2. Another specimen of about the same size varies as 8.25, 9.5, 9.3, 8.1, 9.5. The average length is always well above 9:1, while one example has an arm as long as 10:1. The armature of the inferomarginal plates is, as a rule, more robust toward the base of the ray, particularly in respect to the actinal series of spines. In some specimens the spines on the basal plates are subequal in length, there being, instead of 5 large spines with small intermediate spinelets, about 7 or 8. Usually, however, the formula already described holds true.

Young: A single half-grown individual ( $R=85$  mm.;  $r=10$  mm.) differs from the fully adult in having slightly shorter arms and more prominent spinules on superomarginals, there being one on

each plate relatively more enlarged than in the adult. The lateral lamelliform spines are slightly narrower, and there are no enlarged spinelets between them and the superomarginal plates. In fact, the whole of the second series of inferomarginal spines is reduced in size and number.

Localities: Type (no. 21145 U. S. National Museum) and 10 specimens from station 4102, Pailolo Channel, between Maui and Molokai islands, 122-132 fathoms, fine gray sand and foraminifera; bottom temperature, 59.7°. One immature specimen from same locality, station 4101, 143-122 fathoms, coral sand, shells, foraminifera.

This remarkable and aberrant *Astropecten* is especially characterized by its large size, long, flat rays, very small disk, and regular longitudinal series of leaf-like marginal spines. It is quite different from any species heretofore described. Owing to the relatively small size of the disk, the species is very fragile at the junction of the arms and disk. Several specimens have a considerable portion of one or two of the arms regenerated.

***Astropecten callistus*, new species.**

Pl. VIII, fig. 3; pl. IX, figs. 4, 4a-4d; pl. XI, fig. 2.

Rays 5.  $R=55$  mm.;  $r=12.5$  mm.  $R=4.4$  r. Breadth of ray at base (between second and third superomarginal), 12 mm.; between fifteenth and sixteenth, 7 mm.

Disk of medium size; rays long, rigid, tapering, narrow, sharp. Interbrachial arcs rounded. General form depressed. Actinal surface subplane, most prominent at mouth angles; abactinal surface subplane to very gently convex; capable of very slight inflation. The rays are characterized by subvertical sides, and they taper most in the basal third, and only very slightly in the outer half, giving a peculiarly attenuate appearance. The terminal plate is large, subcylindrical, and the tip of ray is usually bent upward.

Abactinal paxillar area is compact and well defined to tip of ray, decreasing in width in proportion to ray. Paxillae are large and close set, largest in interradial areas and at base of ray, conspicuously decreasing in size toward the center of disk, and much more gradually toward tip of arms. Each paxilla consists of a rather low, cylindrical pedicel, nearly flat-topped, surmounted by a central group of spaced granules, stout, round-tipped, and varying in number from 3 to 8, or even 10. The central 3 or 4 are largest. This group is surrounded by a peripheral radiating series of 18 to 20 smaller, slender, clavate spinelets or elongated granules, the whole very regular and elegant in appearance, and much resembling a composite flower. In the largest specimen ( $R=64$  mm.) there are as many as 24 spinelets in the marginal series, and 12 to 15 in the central group. On disk the pedicels are sometimes elliptical in section, and usually so on the radial portions of the rays. The pedicels are expanded into a fairly large, stellate base. These plates, which are close together and which are joined by their lobes, are generally circular or subhexagonal in contour, the processes, about 6 in number, being short, abrupt, and round-tipped. The latter impinge upon neighboring plates, the papulae passing through the interspaces between them. The papulae are single, and are disposed generally over the abactinal surface.

Superomarginal plates, about 40 in number from the median interradial line to tip of ray, are rectangular, about as high as broad, except in interbrachial arc, where the plates are confined almost entirely to the side of ray, to which they form a uniformly arched margin. The exposed surface of the plate is very slightly convex along its transverse axis, and with regard to the longitudinal axis the plates form a very even arc. They are devoid of spines, and are covered with rounded, subconical granules, largest at upper end of plate, becoming papilliform in grooves between the exposed surfaces and at lower end. In the largest specimen 1 or 2 of these granules are enlarged on the marginal angle of ray, but they are quite inconspicuous.

The exposed surface of each inferomarginal, like that of superomarginals, is separated from its neighbors by a fasciolar groove, and there is also a conspicuous groove between the upper and lower series, seen when the ray is viewed from the side. On outer third of ray the 2 series of marginal plates do not always exactly correspond, but there is considerable variation in this respect. Inferomarginals encroach scarcely more on the actinal surface than do superomarginals on the abactinal, except in interbrachial arc. They form an arched bevel to the margin of actinal area, and in some specimens extend just a trifle laterally beyond superomarginals. Each plate bears a row of 3, often 4, short, flattened, tapering, pointed spines, disposed along the median transverse line of the plate.

These spines are usually subequal, or the median slightly the longest, but occasionally near base of ray the uppermost spine is hardly half as long as the second. There are often 4, and rarely 5, spines on the first few plates, and the innermost spine is near the inner end of the plate, the others being subequally spaced. On outer portion of ray there is considerable irregularity in the spines, the 2 upper often being placed in a longitudinal or oblique series near together, separated from the inner or third spine. Inferomarginal plates are further covered with small, papilliform spinelets, those on the upper end of the plate similar to granules of adjacent portion of superomarginal. They increase in length toward the inner end of the plate, where they are much larger.

Adambulacral plates with convex margin to furrow. The armature consists of 5 long, flattened, slender, round-tipped spines disposed in a fan-shaped series. The median spine is longest, somewhat saber-shaped, but round-pointed, and the lateral spines, which form a graduated series at either side, present their flat sides to furrow. The lateralmost furrow spines are really the lateral members of the first actinal series of 3, the central spine of which resembles the laterals. On the outer end of plate is a longitudinal series of 3 or 4 usually considerably shorter spines. When there are but 3 the spines average slightly larger. The armature as a whole has an expanded character resembling *Astropecten* in general.

Mouth plates are small but prominent actinally, with a numerous armature regularly arranged. Marginal series consist of 6 flattened spinelets, of which 2 are placed at the inner angle as teeth, and 4 form a graduated series along the edge of the plate toward furrow. Marginal series is continued along the edge of plate adjacent to first adambulacral as a row of numerous, shorter, and much slenderer spinelets. The actinal surface bears a superficial series of about 15 slender, tapering spinelets placed along suture margin and increasing in size toward the teeth. A parallel series of 8 or 9 similar spinelets extends along surface of plate between marginal and superficial series, but this is lacking on the inner third of plate.

Actinal interradial areas are rather small; paved with fairly large, irregular, overlapping plates arranged in more or less regular series extending from inferomarginals to adambulacrals. These intermediate plates extend in a single (longitudinal) series nearly half the length of ray or to fifteenth inferomarginal, but the outer plates are very rudimentary. In the interradial areas the plates may be described as rudely shield-shaped, or oval, with a notched border. There is a prominent keel on the actinal surface of each, extending lengthwise of plate (interradially), and this keel forms a beak at the inner end of each plate, overlapping the outer edge of the adjacent plate. The plates consequently imbricate, and this is more pronounced in the large than in the small specimens. Armature consists of a series of radiating, slender spinelets of different lengths, placed in a peripheral irregular series about the keel. These spinelets are about the size of those covering the inner portion of inferomarginals. There is also a central enlarged, tapering spinule or group of 3 to 6 spinules, all forming a very ornamental paxilla crown on the keel. Those plates adjacent to the adambulacrals have rather larger spinelets than the others, and on ray their armature is arranged in a radiating coordinate group. Usually the marginal spinelets on the outer side of the keel of all the plates are conspicuously the longest. These peripheral spinelets project over rather wide fasciolar furrows, between the carinations of the plates.

Superambulacral plates are present, well developed on basal half of series but rudimentary beyond the middle of ray. Tube feet are conical, without sucking disks. Anal pore present, minute.

Color in life nearly white, except the tips of the rays and a small area in the interbrachial arc on abactinal surface, which are carmine to bright vermilion or orange vermilion. The interbrachial area is triangular or crescent-shaped and the central portions of the paxillæ are uncolored. In alcohol all the red disappears.

Variations: The variations are all of a minor character and are mostly due to age. Aside from this, however, some difference is apparent among the specimens in the relative width of the interbrachial arc and consequent tenuity of arms, but this seems due to the degree of inflation of the paxillar area. There is one specimen with 6 rays.

Young: The smallest specimen ( $R = 5$  mm.,  $r = 3$  mm.), from the stomach of an adult, is quite different in general shape, the disk being large and the rays short and broad. Actinal intermediate areas are already prominent and the spinelets of actinal and granules of abactinal paxillæ fewer in number. Mouth plates have but 2 series of spinelets, marginal and superficial; no inferomarginal spines. Adambulacral armature much as in adult. Most of the stages intermediate between this and the adult are represented.

Localities: Type (no. 21146, U. S. National Museum) from station 4079, north coast of Maui, 143-178 fathoms, gray sand and foraminifera; bottom temperature 60.8°. Taken also at the following stations:

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
		<i>Fathoms.</i>	
3810.....	South coast of Oahu Island.....	211-53	Fine coral sand.
3835.....	South coast of Molokai Island.....	169-182	Fine brown sand and mud.
3957.....	Vicinity of Laysan Island.....	220-173	Fine white sand.
4044.....	West coast of Hawaii Island.....	233-193	Fine gray sand.
4045.....	do.....	193-147	Coral sand, foraminifera.
4079.....	North coast of Maui Island.....	143-173	Gray sand, foraminifera.
4080.....	do.....	173-202	Do.
4114.....	Northwest coast of Oahu Island.....	154-195	Coral sand.

This species is distributed, therefore, from Laysan to Hawaii, and its vertical range varies from 169 to 233 fathoms (31 specimens).

Young ophiurans, and a young of the same species were found in the stomach of this starfish.

This species is very abnormal *Astropecten*, if indeed it belongs in that genus at all. The actinal interradial areas are well developed and are paved with strongly imbricating plates, while the inferomarginals are relatively narrow for the genus. The general habit recalls *Tethyaster subinermis* of the Mediterranean region, although the disk is smaller. The superambulacral plates are less well developed than in typical *Astropecten*, and the plates forming the bases of the paxillæ are lobed. An anal aperture is present. This, however, has been found in *Astropecten americanus* by Verrill. *Astropecten mesactus* Sladen has fairly large interradial areas, but differs considerably from this species in proportions and details of structure.

Prof. Verrill has examined a specimen and believes it to be an *Astropecten*.

**Genus CTENOPHORASTER, new.**

Type *Ctenophoraster hawaiiensis*, new species.

Size large. Disk relatively very small. Rays long, narrow at base, and tapering to a blunt extremity. General form depressed, flattened.

Marginal plates of both series with well-developed ridges separated by deep, narrow, fasciolar channels. Superomarginal plates devoid of spines or any enlarged spinules or tubercles. They are much wider than high (except for a short distance in interradial arc) and are flattened, being confined almost entirely to the abactinal surface. Inferomarginals are very wide, extending laterally beyond superomarginals, armed with 3 oblique lateral series of numerous close-set, slender spines, which are continued toward the inner end of plate as a double series.

Abactinal area with large paxillæ, the pedicels of which are stout, cylindrical, and close-set, their bases flaring slightly to form roundish plates. Integument tough.

Actinal interradial areas fairly large, considering the reduced size of the disk, paved with round plates, which extend as a single series between inferomarginals and adambulacrals nearly to tip of ray (fifteen-sixteenths of total length). They are armed with a diverging group of numerous stout, blunt, tapering spinelets, and on disk each plate bears an enlarged, slender, central spinule surrounded by 2 to 5 shorter ones, the periphery of the tumid plate being adorned with a single series of numerous papilliform spinelets.

Armature of adambulacral plates consists of a furrow series of 4 or 5 spines, followed by 3 series of 3 or 4 spines each, on actinal surface. All are stout but slender, the furrow series being slightly flattened.

Well-developed and stout superambulacral plates are present. Ambulacral furrow narrow, deep, with almost perpendicular sides, the margin being slightly overhung by the adambulacrals.

Madreporic body small, situated rather nearer margin than midway between it and center of disk.

This genus is next to *Astropecten*, from which it differs in having a single series of small intermediate plates interposed between the adambulacrals and the inferomarginal plates. Its long rays,

generally flattened form, very small disk, and the low, broad superomarginals confined almost entirely to the abactinal surface give the form a different facies from *Astropecten*. The broad, band-like inferomarginals and the adambulacrals are much like *Astropecten*, although the armature of the former is very different from any species with which I am acquainted.

***Otenophoraster hawaiiensis*, new species.**

Pl. III, figs. 1, 1a-1e; pl. V, figs. 1, 2; pl. VI, figs. 1, 2.

Rays 5.  $R = 150$  mm.;  $r = 22$  mm.;  $R = 6.8$  r. Breadth of ray at base (between third and fourth superomarginals) 27 mm; dorso-ventral dimension of ray at base 10 mm.

Rays long and moderately slender, very gently tapering from a narrow base to a blunt extremity. Disk small. General form decidedly flattened, the sides of arms being low and rounded. Abactinal surface plane; actinal surface gently convex, with a very broad even bevel to the sides. Interbrachial arcs acutely rounded.

Abactinal paxillar area is compact, the large paxillæ being arranged in regular transverse rows along the marginal portion of the area, these series becoming interradiar in the interbrachial arc. Along median radial line of ray the paxillæ are smaller, crowded, and not arranged regularly, so that a very distinct narrow area is seen running from tip of ray nearly to disk. Paxillæ are more compact in the center of disk than at sides. The largest paxillæ are found in the interradiar areas near, but not precisely at, the center of disk, while the largest on the rays are about midway between the median radial line and margin. Each paxilla consists of a stout conical pedicel, flaring at base and summit, surmounted by a variable number of much shorter papilliform spinelets, either united into a compact group, or with marginal series radiating. The larger paxillæ have 20 to 28 spinelets in a central group, surrounded by the same number in a marginal series. A typical large paxilla of the arm possesses about 15 or 16 spinelets in a peripheral series, and 12 to 14 in central group; one from the median radial line, 8 to 10 in peripheral series, and 3 to 5 in the central group. Papulæ numerous, large except along median radial line, where they are small.

Superomarginal plates, 60 in number from the interradiar line to extremity of ray, are much wider than high, except in interbrachial arc, and encroach conspicuously upon paxillar area, forming a rather flat border. Inferomarginals extend beyond superomarginals, and define margin of ray. The latter are wider than long, especially the first 3 plates, which are only about half as long as the others and form a perpendicular or slanting wall to the interbrachial arc. Surface of plate is covered with papilliform granules becoming spinelets in the well-developed fasciolar grooves; no enlarged spines or tubercles are present.

Inferomarginals correspond in number to superomarginals; short (2 mm.) and very wide (10 mm.), appearing as bands, stretching from actinal intermediate series to margin of ray, and forming a broad, slightly rounded bevel to border of actinal area. Upper or outer end of each plate extends laterally beyond the superomarginals, and is tumid for the reception of spines. Armature consists of many slender spines and spinules, with still smaller spinelets, grouped into 3 (rarely 4) obliquely transverse curved rows on the outer end of the plate. These series encroach slightly upon the actinal surface of plate, where they merge into 2 irregular transverse rows along the aboral margin, which are continued to the innermost end of the plate. (See diagram pl. III, fig. 1e.) Of the three outer or lateral series, the first, that situated nearest median line of plate is largest, consisting of 7 or 8 slender, slightly curved, tapering, pointed spines, which are closely pressed to the side of ray and overlies the other 2 series (pl. III, fig. 1a). The upper 3 or 4 spines are on the abactinal surface. The second series is arranged parallel to the first, and consists of 5 to 7 similar but slightly smaller spines, while the third series has only 4 spines, still smaller, and arranged along aboral margin. The 2 longer series of actinal spines are somewhat irregular. That nearest the median line of plate consists of 5 to 7 slender flattened, blunt spines, about the size of those of first series of marginal spines, with which this may be considered continuous. These spines are turned upward or outward, are closely appressed to ray, and usually lie crowded in the furrows between adjacent plates. About the base of each, on the adoral side, is a cluster of spinules, 1 to 4 to each spine. These increase in size toward the inner end of the plate, being about one-third to one-half as long as their adjacent spines. There is usually an odd spine at the inner end of plate, in the median line just adoral to the lowermost spine of the regular series. Both are usually sharp. The second actinal series consists of a number (about 7 or 8) of spinules

irregular as to length and position, scattered along the aboral margin below the inner marginal series. They are wholly covered by the much larger spines of the first series. General surface of plate is covered with papilliform spinelets, crowded, becoming slenderer in the deep fasciolar grooves.

Adambulacral plates, wider than long, have a convex margin to furrow. Armature as follows: (1) A furrow series of 3, with which are associated the lateral spines of the first actinal series, making usually 4 or 5 spines on the margin. The median spine is stoutest, most flattened, the 2 laterals decreasing in length and forming a palmate series. The furrow spines proper are truncate or round-tipped, tapering and compressed, the edge being toward furrow. The median spine reaches quite across the furrow. (2) Actinal surface bears 3 or 4 longitudinal series of tapering spines, decreasing in length toward the outer end of plate. The first, or inner, 2 series have about 3 spines each, while the outer 2 commonly have 4, although there is much irregularity. The spines of the inner 2 series are longest, and are slightly flattened, the broad side to furrow.

Opposite each adambulacral plate is a roundish intermediate plate, with a central raised tabulum, the series of which extends to the 55th inferomarginal or to within 12 mm. of the tip of ray (pl. III, fig. 1.) Actinal interradial areas fairly large, considering the small size of disk, and paved with round plates like those of the rays. There are about 16 of these plates, omitting the series adjacent to the adambulacrals, and they do not extend beyond the second inferomarginal. Intermediate plates of ray are armed with a radiating group of 15 to 18 blunt spinelets, resembling the papilliform spinelets of inferomarginals but larger. Rarely a central spinelet is enlarged. In interradial areas each plate bears a conspicuous, bluntly pointed, tapering spinule, about which are grouped 2 to 5 shorter spinelets. Surrounding these is a peripheral series of numerous, still shorter, papilliform, slender spinelets, radiating to form a rosette, the whole armature surmounting the central tabulum of the plate and forming a very ornamental paxilla-crown. On those intermediate plates adjacent to adambulacrals the armature is the same as on ray, except for the presence of 1 or 2 larger central spinelets.

Mouth plates are rather prominent, bent inward toward actinostome. At the inner angle there are 4 heavy, slightly flattened, blunt spines, placed in a perpendicular comb, the largest nearest mouth, and the series of companion plates are close together, forming a double phalanx at each mouth angle. This series is continued toward outer angle of plate as a row of stout, slightly flattened, blunt spinules, along the margin of suture. They are all much smaller than the inner teeth, and become slenderer and weaker as they approach the outer end of plate. Marginal spinelets small, flattened, rounded or truncate at tips, extending in a perpendicular series along border, subparallel to the 4 "teeth," and appressed to an intermediate row of spinelets. Between marginal and superficial series are 3 parallel intermediate series, the one nearest teeth slightly larger than marginal spinelets. These 3 intermediate series are continued toward the outer end of plate as slender and longer spinules forming a bristling armature to actinal surface. A deep fasciolar groove intervenes between the mouth plates and adjacent adambulacral, and that surface of the former which forms the side wall of groove is covered with minute papilliform spinelets. Superambulacral plates well developed.

Madreporic body small, situated slightly nearer margin than midway between it and the center of disk. Ridges are rather coarse, having alternate swellings and constrictions, and cross the plate interradially in direction.

Color in life unknown; in alcohol dull brown.

Locality: Station 3935, vicinity of Laysan Island, 57 fathoms, white sand, broken shells, coralline; bottom temperature 71.1°. Type no. 21147, U. S. National Museum.

This species may be distinguished by its long rays and generally flattened form, by the unarmed superomarginal plates confined almost entirely to the abactinal surface; by the broad, band-like inferomarginals with their numerous small spines; and especially by the series of intermediate plates between the adambulacrals and inferomarginals. The species has the general facies of a flat, long-rayed *Astropecten*, with acutely angular yet rounded margin to rays. It is sufficiently unlike *Astropecten*, in the presence of a series of actinal intermediate plates on the ray and in the character of inferomarginal armature, to warrant its segregation from that much overburdened genus.

Genus *TRITONASTER*, new.Type *Tritonaster craspedotus*, new species.

General form flat and depressed; disk of medium size; rays 5, moderately long, tapering gradually from a rather broad base to a pointed tip.

Superomarginal plates much smaller than inferomarginals, especially on the outer part of ray; confined chiefly to abactinal surface; first 10 bearing weak spinules on the abactinal (=inner) edge. Inferomarginals very tumid, each bearing a transverse comb of 4 to 7 long, slightly curved seta-like spines, and, except in interbrachial arcs, defining ambitus. Fasciolar groove at bottom of each broad sulcus between 2 inferomarginal plates, or rather between the summits of their tumid portion, shallow, not specialized, packed with minute spinelets. Covering of marginal plates delicate papilliform spinelets, giving a velvety texture.

Abactinal integument thin, capable of being inflated; covered with small paxillæ which are arranged in regular rows at sides of arms and disk. Those of the median radial portion of arms and center of disk without regular arrangement, and smaller and not uniform as to size. Bases of paxillæ, or abactinal plates, are of different sizes, roundish, and spaced. Papular pores conspicuous, arranged irregularly about the plates, and in 2 series between the lateral abactinal rows of paxillæ, to which region they are confined on the outer half of ray. Actinal interradiar areas small, paved with small, roundish plates, a single series of which extends far along ray, but beyond the fourth inferomarginal these plates are only rudiments attached to edges of marginals. Actinal intermediate plates are covered with a compact group of delicate spinelets.

Adambulacral plates are massive, with convex or angular margin to furrow. Armature consists of (1) a furrow series of a few stout spinelets flattened and blunt, and (2) on the actinal surface many slender spinelets arranged in 5 or more irregular, longitudinal rows. Usually about 6 of these spinelets are grouped into a pedicellarian apparatus near the inner, aboral corner of the plate. Ambulacral furrow wide, the tube-feet without suckers.

Superambulacral plates present, slender, but well developed.

Mouth plates prominent, with about 3 series of actinal and 1 of marginal spines. Actinostome fairly large.

Madreporic body moderately large, situated about its own diameter from the margin. Striations numerous, irregular, radiating from an eccentric point.

This genus is characterized particularly by the structure and armature of the marginal plates. It is probably nearly related to *Astropecten* but differs from that genus in the peculiar, very tumid, inferomarginal plates and the reduced superomarginals, which, on the outer part of the ray, are almost abortive. The fascioles are much reduced in size and are quite unlike those of *Astropecten*. Indeed, the structure of the inferomarginals reminds one more of *Persephonaster*, to which the abactinal integument also is similar. Young of *Tritonaster* resembles *Astropecten* superficially, as might be expected, but the peculiar characters are greatly intensified in the adult. The presence of a series of rudimentary actinal intermediate plates, between the adambulacrals and inferomarginals (really attached to the actinal edge of the latter), is, I believe, also a character of generic importance.

***Tritonaster craspedotus*, new species.**

Pl. VIII, fig. 4; pl. IX, figs. 1, 1a-k; pl. XI, fig. 1.

Rays 5. R=61 mm; r=12 mm. R=5 r. Breadth of ray at base, between first and second superomarginals, 13.5 mm.

Rays moderately long, flexible, fragile, tapering continually and gradually from base to a sharp point. Interbrachial arcs acute but rounded. Disk rather small. General form depressed and flat, the marginal plates forming a beveled edge to ray, except in interbrachial arcs, where the sides are perpendicular. Abactinal area subplane, thin, capable of being inflated or depressed. In some specimens it is often so depressed that the inner ends of the ambulacral ridges form 5 humps on disk. Actinal area is plane. Ambulacral furrow takes up about a third the width of ray. Tube feet in 2 rows, conical, without sucking disks.

Abactinal paxillar area is not very uniform in character except at sides of area, where the paxillæ are arranged in regular transverse rows and are uniform as to size; nor is the area at all compact.

Along median radial area of ray and central portion of disk, paxillæ are not regularly arranged nor uniform in size. Paxillæ are small, smallest in central portion of disk, and are widely spaced, giving considerable flexibility to the dorsal integument. The paxillæ of the regular series are rather close together but the rows themselves are separated by nearly twice the diameter of a paxilla. The paxillæ consist of a short pedicel or tabulum surmounted by from 4 to 20 very delicate, subequal spinelets, either coordinated into a compact group, or with outer spinelets diverging. Scattered in among the larger paxillæ are many small, intermediate ones, with from 4 to 10, usually coordinated, spinelets. The diversity in size of paxillæ give to this species a very characteristic appearance. Papular pores are fairly large and numerous, and surround the paxillæ in a series of 4 or 5; arranged in regular double rows between the lateral regular series of paxillæ; not numerous toward tip of rays.

Superomarginal plates, about 28 in number from interradiial line to tip of ray, are very much smaller than inferomarginals, except the first 4 or 5 in interbrachial arc, which are only slightly smaller. They decrease rapidly in size toward tip of ray, much more rapidly than inferomarginals, the latter with their armature of long delicate spines forming the border of ray. In interbrachial arc the height (or width) of superomarginals equals length, and by the ninth plate the width has so decreased that it equals only one-half the length. The plates further decrease to mere bands, or ossicles placed end to end, forming an inconspicuous border to the paxillar area (pl. ix, figs. 1 h-j). All are somewhat tumid. Margin of plate toward paxillar area is slightly convex, and owing to tumidity is raised slightly above the level of the area. Plates are covered with tiny, uniform, very delicate, close-set, papilliform spinelets, giving a velvety texture to the surface. Each spinelet is slightly clavate, blunt. Membranous investment is invisible. The first 10 superomarginals each bear a delicate, tapering, sharp spinule on the inner margin, placed rather nearer the aboral than adoral end; those of first 2 plates short, becoming longer on following 4 or 5, then short again. All are very fragile and none are as long as their respective plates.

Inferomarginals correspond to superomarginals in number, and encroach upon actinal surface more than do the superomarginals upon abactinal. Actinal margin of plate is convex, abutting against adambulacrals throughout the greater part of the ray, as the actinal intermediate plates are quite inconspicuous. Plates are set obliquely to long axis of ray; very tumid, the lateral portion being raised into a conspicuous boss, so that when viewed from either above or below the margin of ray appears to be deeply scalloped, the summit of the bosses being fairly acute, the sulcuses between angular. Each boss is surmounted by a comb of remarkably long, slender, delicate, tapering, slightly curved, sharp spines, appressed closely to side of ray, those of outer half of ray extending obliquely over, and resting on, the abactinal area. On first and second inferomarginals the tumidity is not so pronounced as on the rest, and the spines are shorter. On first plate there is a dorso-ventral series of 4, rather widely spaced, the uppermost but one being longest, which when bent upward reaches the middle of superomarginal. Occasionally only 3 short spines are present. On second plate is an oblique series of 3 or 4 spines, exceeding the plate in length, with usually 1 or 2 odd spines set close to and on aboral side of the 2 upper members, and an odd spine on ventral margin. On third plate is an oblique series of 4 (3 to 7) spines, situated nearer upper margin of plate, the lowermost 3 spines being longest (3-5 mm.). From fourth to eighteenth or nineteenth plates the usual number of spines is 6 to each comb (5 in small specimens), varying on some plates to 5 and rarely to 7. Owing to the rapid reduction in the size of the superomarginals, the series of spines moves more and more abactinad, so that on the outer two-thirds of ray the bases of most of the spines can be seen when the specimen is observed directly from above. The longest spine is usually second from bottom of series, and the uppermost is shortest. The spines reach their maximum length about two-thirds the distance from base of ray, where they attain 7 mm. in length (about one-ninth of R), and are fairly long to within 5 or 6 plates of the extremity. General surface of plates is covered with minute papilliform spinelets, similar to those of the superomarginals, but a trifle longer on lower portion of plates.

Adambulacrals plates are massive, set obliquely, with an angular margin to furrow; slightly wider than long in basal half of ray; longer than wide in distal half. Armature rather crowded and somewhat variable; in general as follows: (1) A furrow series proper of 3 long, diverging spinelets, the median longest and much flattened, saber-like, the edge to furrow. The lateral spinelets are also somewhat compressed at base. With these are usually associated 2 actinal spinelets, 1 at either end of the series, which are really the lateral members of the first actinal series but on account of the extreme angularity of the furrow margin appear to belong to the furrow group, and toward the extremity of ray the distalmost spinelet of the second actinal series also stands on the furrow margin, making

6 in all. (2) Actinal spinelets of plate, 15 to 30 in number, decrease in length from the furrow toward the marginal plates. There are 3 fairly regular longitudinal series in the inner half of plate. At base of ray the first series has 3 or 4 spinelets, the second 3 to 5, and the third about 4 or 5. On outer portion of ray the spinelets are rather more numerous. Besides these, on the outer half of plate is a variable number of smaller spinelets, not regularly arranged. Many plates have 5 or 6 spinelets, usually on the aboral side, arranged in a definite, conical, pedicellarian apparatus.

Actinal interradial areas are small, paved with small, roundish plates, the series of which, in a rudimentary condition, extend about two-thirds the length of ray (to twelfth or fifteenth inferomarginal). In interradial areas the plates are arranged in series extending from inferomarginals to adambulacrals, and the number of series, with the number of plates in each, is as follows: First inferomarginal, 3 series, 5, 4, and 3 plates, respectively; second inferomarginal, 2 series of 2 plates; third inferomarginal, 2 plates adjoining sixth and seventh adambulacrals. Beyond this point intermediate plates become rudimentary, 1 or 2 being fastened to the lower border of each inferomarginal. Armature consists of long, delicate, slender spinelets disposed in a group similar in all respects to those of adjacent portions of adambulacrals. Spinelets on those plates nearest interbranchial arc are shorter, resembling more nearly the spinelets of adjoining inferomarginals.

Mouth plates are elongate, the united pair ovoid, prominent, broadest toward actinostome. Armature conspicuous and irregular, as follows: (1) A marginal series of about 6 short, blunt, usually somewhat flattened spinelets, which, with those of the companion plate, form a compact, crowded, fan-shaped group at each mouth angle, the angular space between the meeting series being filled with similar spinelets. (2) On actinal surface a superficial series bordering the suture, stout, short, flattened, with rounded, truncate or flaring, leaf-like tips, and narrowing at base; this sort confined to the inner half or two-thirds of plate, the outer portion of series being composed of slenderer, flattened, sharp spinelets. Innermost 2 or 3 spinelets of superficial series are often enlarged to form teeth (*a*, fig. 1 e, pl. ix), which are flattened, oblanceolate, blunt, or truncate. The edge of the plate toward actinostome is angular, like the adambulacrals, so that the marginal series of 6 or 7 spinelets (*b*, fig. 1 e, pl. ix) is also angulated, and is continued along the border adjacent to the first adambulacrals as a series of weaker and smaller spinelets. Between this and the superficial series are 2 more or less irregular rows of similar but larger spinelets placed parallel to the former and increasing in length toward the inner end of plate.

Madreporic body is fairly large, situated about its own diameter distant from margin; striations of medium coarseness, radiating from an eccentric point.

Color in alcohol bleached yellowish to whitish; in life, unknown.

Localities: Type (no. 21148, U. S. National Museum) from station 3918, 8 miles southwest of Honolulu, 294-257 fathoms, white sand and mud; bottom temperature 44.5°. Taken also in this vicinity at station 3914, 289-292 fathoms, gray sand, mud; and at station 3919, 257-220 fathoms, gray sand; 16 specimens taken in this cruise. Cruise of 1891: Station 3473, south coast of Oahu Island, 313 fathoms, fine gray sand; 1 specimen.

This peculiar species was taken only in a very limited area off the south coast of Oahu Island. It is readily distinguishable by its delicate paxillar area, small superomarginal plates, and especially by the remarkably tumid inferomarginals with their armature of long, exceedingly delicate, slightly curved spines.

The stomach contents of several specimens included small gastropods, pteropods, ophiurans, young sea-urchins, ostracod and macruran crustaceans, and small worms in tubes.

#### Genus *PSILASTER* Sladen.

*Psilaster* Sladen in Narr. Challenger Exp., vol. v, 1885, p. 611. Type, *Astropecten andromeda* Müller and Troschel.

#### *Psilaster attenuatus*, new species.

Pl. III, fig. 3, 3a-d; pl. VII, fig. 4; pl. VIII, fig. 1.

Rays 5.  $R=107$  mm.;  $r=17.5$  mm.  $R=6$  r. Breadth of ray at base (between second and third superomarginal plates) 18.5 mm.

Rays elongate for genus, rather narrow, with a relatively narrow base, thence gently tapering to a slender sharp extremity. Interbranchial arcs acute, but sharply rounded. Disk relatively small. Abactinal area plane; actinal area plane; disk capable of slight inflation.

Abactinal paxillar area is rather uniform in character, but not very compact, except in center of disk, the paxillæ being spaced so that the papulæ may be detected between them. The latter are crowded into rows between the regular transverse lines of paxillæ. Along a very narrow median line on each ray, where paxillæ are not regularly placed, the papulæ are wanting, and they appear to be absent also from center of disk. Paxillæ are rather small and decrease slightly in size toward median radial line, extremity of ray, and center of disk. Each paxilla consists of 2, 3, or 4 central papilliform spinelets surrounded by a peripheral series of 7 to 10 similar spinelets. The latter may radiate like the petals of a flower, or the whole form a coordinate group. The more numerous paxillæ possess about 2 central spinelets and 7 to 9 marginal ones, while the largest may have upward to a dozen marginal spinelets. In specimens from off the south coast of Oahu, which differ slightly from the type, the paxillæ are usually more crowded and the spinelets form a coordinate group, giving the abactinal surface a much more compact appearance. In proportion to size of animal the paxillæ of these specimens are a trifle larger than the type, but the number of spinelets does not appear to average greater.

Superomarginal plates, 57 in number from the interradian line to extremity of ray (or 60 in largest specimens, with  $R=120$  mm.), form a somewhat rounded bevel to margin of ray. Plates short and high (or wide), the longest being the tenth to fifteenth from the interradian line. Each plate has a specialized ridge, the ridges of consecutive plates being separated by rather narrow transverse fasciolar grooves, for the most part obscured by crowded papilliform spinelets. It is the exposed, very slightly tumid face of these ridges which forms the outer or exposed face of the plates on the dorso-lateral face of the ray. The plates are covered with crowded, short, papilliform spinelets, each of which is invested with a membranous sheath. On the outer two-thirds of the ray (beyond the eleventh or twelfth superomarginal) each plate has 1, 2, or sometimes 3, short, delicate spinules placed in a median transverse row at about the middle of the plate. The spinelets surrounding these are flattened or squamiform. The spinelets lining the sides of the fasciolar grooves are very much slenderer than those of the exposed surface of the plates, the latter being much more crowded about the edges than in the center.

Inferomarginal plates correspond exactly to the superomarginals, and form an abruptly rounded margin to actinal area. When the ray is viewed from side the whole height of supero and inferomarginal plates can be seen. Inferomarginals are considerably higher (or wider) than long, and like the superomarginals possess an especially elevated ridge, the successive ridges (the exposed surface of the plates) being separated by fasciolar grooves filled with papilliform spinelets. Plates are covered with crowded spinelets, similar to those investing the superomarginals, which increase slightly in size toward the actinal intermediate plates. Each plate carries a row of 3 flattened, tapering, sharp spines, directed obliquely upward and toward end of ray. These are placed in a median dorso-ventral line; the middle spine being longest (in length equaling 2 inferomarginal plates, or their exposed surfaces). All 3 are closely appressed to the ray. On outer third of ray there are only 2, the upper spine being absent. On the proximal 2 or 3 inferomarginals there are usually only 1 or 2 spines, reduced in size. A few of the largest specimens possess a series of 4 spines on the more proximal inferomarginals, but the number is usually 3. In the specimens from the south coast of Oahu, already alluded to, the spinelets covering both supero and infero-marginals are more thickly covered with membrane, appear more fleshy, and tend to be more squamiform. Those of the inferomarginal plates are particularly soft. They increase in size actinally, on the lower part of the plate being rather larger than the papillæ of adjacent actinal intermediate plates.

Adambulacral plates massive, about as wide as long, with an angular margin to furrow. The plates are separated by fairly conspicuous sutures, forming shallow grooves usually continuous with the fasciolar grooves between the marginal plates. Adambulacral armature as follows: (1) A furrow series of 7 or 8, occasionally 9, rather long, flattened, blunt spinelets, the central ones being very slightly the shortest. These spinelets are so arranged that about 4 are placed along either side of the angular margin. The median 2 or 3 spinelets are compressed so that the edge is toward the furrow, but the lateral ones present their flattened face thereto. Considerable of the flattening, which is more pronounced at the base of the spinelets, is due to the membranous envelope of each. (2) The remaining spinelets, more or less grouped and 10 to 15 in number, form a rather compact group on the actinal surface. They are tapering, blunt, and are usually disposed in 3 irregular longitudinal rows. These actinal spinelets are often thicker than the marginal series, and are invested with a rather pulpy membranous sheath, which frequently flattens in the outer spinelets of plate (especially in specimens

from off the south coast of Oahu). When the membranous investment is removed from any of the spines they are seen to be delicate, slender, and pointed.

External to each adambulacral plate is a small intermediate plate (or a transverse series of 2, 3, or more), the longitudinal series of which extends along the ray to about the fortieth adambulacral, and thirty-sixth inferomarginal plate. This series is a continuation of the small roundish or elliptical plates covering the actinal interradiial area. The number of intermediate plates opposite each adambulacral and extending interradiially, or transversely to the corresponding inferomarginal, is as follows: One small unpaired interradiial intermediate plate adjacent to outer end of mouth plates; first adambulacral, 4 (the series not reaching as far as inferomarginals); second and third adambulacral, 7 (series meeting first inferomarginal; fourth and fifth, 4 or 5; sixth, 4; seventh to fourteenth, 3; fifteenth to twenty-fourth, 2; twenty-fifth to fortieth, 1. In young specimens these plates are naturally fewer in number. New plates are added adjacent to the inferomarginals. The armature consists of small, blunt papilliform spinelets, grouped or arranged in a double, longitudinal series. They are similar but slightly smaller than adjacent spinelets of the adambulacral plates. All are characterized by a soft membranous investment or sheath.

Mouth or dental plates fairly prominent actinally; narrowly ovoid; rather elongate with a regular armature, consisting of a single line of stout, slightly flattened spinelets with rounded or truncate tips, arranged along margin of plate adjacent to the interradiial suture. On outer free margin of plate, placed higher than the first series, is a second series of smaller, truncate, flattened spinelets, closely appressed to the outer side of the superficial series. Innermost spines of the superficial series stouter, longer, and more flattened than the rest, forming at each mouth angle two prominent teeth, with which are also associated two smaller spines of the second series. There is considerable variation in the relative size of these 4 teeth, but the lateral are much smaller and weaker than the median pair. They are usually directed away from the actinostome, appressed against the adjacent spines of their respective series, and are hence very inconspicuous. Space between the superficial series of companion plates fairly wide.

Madreporic body small, situated near margin, about two-thirds the distance from center of disk to inner edge of the superomarginal plates. Striations coarse in adult individuals, beset with scattered tubercular projections; the latter often nearly absent.

Color in life: Abactinal paxillar areas brick red on the disk, shading into vinaceous rufous on arms, and finally to orange rufous at extremity of arms; superomarginal plates pinkish buff, shading into pink on the actinal surface; tube-feet raw sienna. Young individuals pinkish; marginal plates nearly white. Color in alcohol deep brown to dirty yellowish white; young, bleached yellowish.

Variations: With one exception, most of the variations are of a very minor nature, and can easily be accounted for by the difference of size or age. There is, however, a group of specimens from off Diamond Head on the south coast of Oahu Island which have already been alluded to in the foregoing description; all these specimens are characterized by shorter and thicker rays (as compared with the disk) than those possessed by the type, and the paxillæ seem to be just a trifle larger and are more crowded, giving the paxillar area a more compact appearance; the spinelets of the marginal plates are fleshier and more squamiform. This form can be separated at once from the typical specimens throughout all the stages of growth, as shown in the accompanying figures. (Pl. XLIX, figs. 2 and 3.) None of the thick-rayed form were taken among the 150 specimens from off West Maui and the Pailolo Channel, but two apparently (almost) typical specimens were taken off Diamond Head, in the same general locality as the thick-rayed variety. The latter appears too slightly and insecurely separated from the typical form to warrant a specific name. Neither is it possible to bestow a trinomial designation upon "this well-marked 'variety'" as some recent writers might be willing to do. Until something more definite is known concerning the different phases or variations (often quite constant and occurring in the same locality) which starfishes are known to exhibit, it seems somewhat ill-advised to pervert the trinomial to such uses. These forms can not be considered as subspecies, at least not in the sense in which ornithologists understand the term, for they are not equivalent to geographical races.

Young stages: The young are considerably different in general appearance from the adult. The smallest specimen has  $R=9$  mm., and  $r=3$  mm. The smallest of the thick-rayed variety has  $R=9$  mm., and  $r=4$  mm. The small specimens are therefore characterized by shorter and broader rays than the adult, few marginal plates, relatively large ocular plates, which bear 3 minute spinelets, less compact

paxillar area, fewer spinelets to the paxillæ, only 2 weak spinelets on the inferomarginal plates instead of the series of 3 of adult, no trace of an enlarged spinule on the superomarginals. The spinelets of the paxillæ radiate, forming beautiful rosettes, and are not clustered in a bunch as is usual in large examples. There are 3 to 5 of these spinelets, representing the marginal series of the adult, the central spinelets being absent. The teeth are much more prominent in little specimens. The transition between this and the adult is represented in the collection. The general facies of the adult is reached when the creature has attained a major radius of about 55 mm., at which age there are something over 40 superomarginal plates. The immature specimens all have a low epiproctal hummock or cone, very pronounced in the little examples, but wholly absent in the fully adult forms. As mentioned in the previous paragraph, all the stages of the Oahu specimens have thicker rays than the typical form.

Localities: Type (no. 21149, U. S. National Museum) from station 4095, northeast approach to Pailolo Channel, between Maui and Molokai islands, 290-286 fathoms, brown mud, fine sand, and globigerina; bottom temperature, 43.9° F. As detailed in the following table, the specimens were taken either from the northeast approach to Pailolo Channel (which separates Molokai from Maui) or in practically the same locality farther out, to the north of western Maui; or they were dredged off the southern coast of Oahu, most of the latter being not quite typical. The longitudinal distribution of *Psilaster attenuatus* extends from 256 to 337 fathoms, the most favorable depth for large specimens being in the neighborhood of 290 fathoms. The nature of the bottom varies, specimens having been taken in globigerina ooze and mud, fine volcanic sand and rocks, gray mud and fine sand, sand and shells, fine gray sand, brown mud and fine sand with globigerina.

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
3865	Northwest approach to Pailolo Channel, between Maui and Molokai islands.	<i>Fathoms.</i> 256-283	Fine volcanic sand and rocks.
3866	do.	283-284	Gray mud, fine sand.
3867	do.	284-290	Fine sand, mud.
3883	do.	277-284	Globigerina ooze.
3884	do.	284-290	Globigerina mud.
3908	South coast of Oahu Island.	304-308	Fine white sand and mud.
3909	do.	308-322	Do.
3910	do.	311-337	Fine gray sand, mud.
3911	do.	337-334	Do.
3916	do.	299-330	Do.
3917	do.	330-294	Do.
3918	do.	294-257	White sand, mud.
4086	North coast of Maui Island.	283-308	Sand, shells.
4087	do.	308-306	Fine gray sand.
4088	do.	306-297	Do.
4089	do.	297-304	Do.
4090	do.	304-308	Do.
4091	do.	308-306	Do.
4095	do.	290-286	Brown mud, fine sand, globigerina.
4096	Northeast approach to Pailolo channel.	272-286	Fine gray sand.

In December, 1891, the *Albatross* made a few dredge hauls off the south coast of Oahu and secured about 60 specimens, the greater number of which are typical. They were taken at stations 3470, 343 fathoms, white sand; 3471, 337 fathoms; 3474, 375 fathoms; 3475, 351 fathoms (four-fifths of the specimens); 3876, 298 fathoms.

This species, of which about 230 specimens have been examined in all stages of growth, is one of the commoner forms of the medium depths. It is characterized by the long graceful rays, and by the form of its paxillæ and the armature of marginal and adambulacral plates. It is most nearly related, among forms already described, to *Psilaster acuminatus* Sladen, which has been taken northwest of Port Hardy, New Zealand, and Simons Bay, Cape of Good Hope. It differs from Sladen's species principally in having longer and slenderer rays, in the covering of the marginal plates, and to a less extent in details of paxillæ and adambulacral armature. The rays of *attenuatus* are even longer relatively than those of *gracilis*; *gracilis*, however, is widely different from *attenuatus*.

Genus *PSILASTEROPSIS*, new.Type *Psilasteropsis cingulata*, new species.

Disk small; rays long, robust, and tapering to a pointed extremity.

Marginal plates massive, conspicuously encroaching on both abactinal and actinal areas; slightly or strongly tumid. Surface of plates covered with squamules, becoming papilliform in groves between. Superomarginal plates devoid of large spines or tubercles; inferomarginals bearing a series of short tapering spines, disposed more or less obliquely and closely appressed to ray.

Abactinal area covered with compact paxillæ, composed of papilliform spinelets grouped in a coordinate bunch on a thick pedicel. Arranged more or less regularly in transverse rows at sides. Abactinal plates (bases of paxillæ) roughly hexagonal, placed rather close together. Papulæ conspicuous, arranged around each plate. They are scarce toward extremity of rays and center of disk.

Actinal interradial areas small, with small intermediate plates which extend only about one-third the length of ray. Intermediate plates all bear groups of papilliform spinelets, which are sometimes grouped to form an incipient pedicellarian apparatus.

Adambulacral plates massive. Armature consists of (1) a furrow series of numerous, rather delicate, subequal, long, uniform spinelets forming a regular, straight-edged comb; (2) on the actinal surface of the plate 2 or 3 irregular longitudinal series of shorter, cylindrical spinelets. These are sometimes grouped to form a conical pedicellarian apparatus on plates near base of rays. Tube feet without sucking disks, large, in 2 rows.

Madreporic plate of medium size, situated rather nearer margin than midway between it and center of disk.

A tiny pore, anal in position, is apparently present. Superambulacral plates present, well-developed.

This genus is erected for the reception of a species which differs in several essential points from true *Psilaster*; namely, in the more massive and distinctly tumid marginal plates, very much reduced fasciolar channels, the more restricted actinal intermediate plates, which do not extend far along the ray, in the regular and more numerous furrow spines of the adambulacral plates, in the large paxillæ which are tabulate, and which give to the abactinal surface a very characteristic appearance. In this genus should be ranked, also, *Psilaster patagiatus* Sladen, which, however, differs from *cingulata* in having incipient excavate pedicellariæ on the superomarginals and in the armature of the mouth plates. The general facies of the two species is much alike. Mr. Sladen, in describing *Psilaster patagiatus*, expressed serious doubts as to the propriety of referring that species to the genus *Psilaster*, and now that a second, similar, well-marked form has been found on the opposite side of the globe, it becomes doubly necessary to segregate the forms.

*Psilasteropsis cingulata*, new species.

Pl. III, figs. 2, 2 a-b; pl. VII, figs. 1, 2, 3; pl. VIII, fig. 2.

Rays 5. R=95 mm; r=18 mm. R=5 r+. Breadth of ray near base (between second and third superomarginal plates) 18 mm.

Rays long, fairly narrow at the base, gently and gradually tapering to an acute tip. Disk small. General form somewhat flat and depressed. Sides of ray nearly perpendicular. Abactinal surface plane; actinal nearly so. Interbranchial arcs acute but well rounded.

Abactinal paxillar area is depressed slightly below the level of the superomarginal plates and extends to the tip of the arm, but is usually greatly reduced in width on the distal third of the ray, being only about as wide as the furrows between the superomarginals of that region. Width of paxillar area at base of ray (between second and third superomarginals) 12 mm. Paxillæ are larger in the center of ray than on side, but are smaller in center of disk. They are subcircular in outline when regarded from above, short, composed of a short cylindrical basal ossicle surmounted by delicate cylindrical spinelets in a coordinated group. In the larger paxillæ a peripheral circle of 15 to 25 spinelets surrounds an irregular central group of about 15. Instead of flaring, the marginal row usually stands perpendicularly, or inclines inward against the central group, giving the paxillar crown a very compact appearance. Spaces between paxillæ are conspicuous, allowing the small papulæ to be clearly

visible; the latter are arranged irregularly in a circle of 6 or 7 around each paxilla. Along the margin of dorsal area the paxillæ are arranged in definite transverse rows, but no order is distinguishable along the median radial line or in center of disk.

Superomarginal plates, 33 in number (varying from 30 to 37 in different individuals) from the median interradiial line to extremity of ray, form a well-defined, broad, and massive border to disk and rays. Each plate is strongly tumid along its transverse axis, so that a broad, rounded well-defined sulcus is formed between successive plates. The extreme tumidity of the marginal plates gives to this species a highly characteristic appearance. The superomarginals are longest (3.5 mm.) toward the base of ray—the third to twelfth plate. Breadth of fifth superomarginal 6 mm. Surface of plates covered with granules and delicate spinelets. Those of the transverse tumid portion are distinctly spaced, flat, roundish, squamiform, but not imbricating, tending to become larger on the abactinal surface; those covering transverse marginal regions of the plate are slender and delicate, giving the appearance of plush. They are longest in the bottom of the groove between the plates, becoming shorter toward the squamiform granules into which they pass insensibly. Under the microscope the latter sort are seen to be cylindrical, slightly swollen at the tips, and invested with a delicate membrane.

Inferomarginal plates correspond exactly to superior series, and they encroach as much upon the actinal surface as do the latter upon the abactinal. They are tumid, the ridge passing obliquely from the middle of the superior margin toward the aboral ventral corner of plate. The upper half of this ridge bears a row of 4 slender, tapering, slightly flattened spines directed obliquely upward and outward and closely appressed to ray. The lowest but one is longest, being about one-third longer than its plate (except on the outer half of ray). These spines decrease in length toward the extremity of the ray, where the series is usually reduced to 3 with an occasional plate bearing 4. The first 5 plates usually bear 5, or sometimes 6 spinules. On the inner third of ray there may be 2 or even 3 short, more widely spaced spinules on the ventral portion of the ridge between the upper series and the ventral margin, situated rather toward the aboral edge of the plate. On the first 2 plates of each ray there is an extra spine or pair of spines on the adoral margin, on a level with the ventral series, the upper spine equalling the length of its plate, and in addition there is an odd spine placed close to, but out of line with, each of the 2 upper spines. General surface of inferomarginals is covered with papilliform spinelets, which become larger, flattened, and squamiform on the median tumid portion of the plate, and more robust toward the ventral margin. They are larger than the spinelets of the superomarginals.

Adambulacral plates large and massive, about 50–54 to the ray, slightly longer than broad, and with a decidedly convex margin to furrow. Armature consists of a furrow series of 11 to 13 long, thin, delicate, laterally-compressed spinelets, standing subparallel or diverging slightly. The outer spinelets are usually slightly the longest, equalling length of plate. Tips of the spinelets form a slightly curved border to the comb. The usual number in the furrow series is 11, decreasing at the tip of ray to 9, or less; covered with delicate membrane. On actinal surface of the plate are 3 irregular longitudinal rows of tapering, membrane-covered, pointed spinelets, there being usually 6 in the first series, 4 or 5 in the second, and 3 to 5 in the third, with often 2 or 3 odd very short spinelets. In basal portion of ray these spinelets are prominent, and are nearly as long as those of the furrow series; they decrease in length and number toward extremity of ray. In the first 3 or 4 plates 5 or 6 actinal spinelets may be grouped to form a pedicellarian apparatus.

Mouth plates are elongate, rather narrow, and prominent actinally, the united pair being elliptical in outline. Their armature is somewhat peculiar, consisting of a marginal series of 9 stout, tapering spinelets shorter than the furrow spinelets of the adambulacrals, the median spinelets of each free margin being the longest of the series. About as many more smaller spinelets are continued along the margin adjacent to the first adambulacral. Along the margin of the median suture is a series of about 16 stout, blunt, flattened spinelets which increase in length toward the inner extremity of the plate, the innermost spine being flattened, long, lanceolate, and directed with its fellow of the companion plate across actinostome. Between the marginal and superficial series is an intermediate series resembling the latter but with fewer spinelets. The peculiarity of the armature is that the intermediate and marginal series, rather closely appressed, continue above (abactinad) the level of the main tooth along the edge of the plate, curving in such a manner as to be directed not toward actinostome, but across the ambulacral furrow. This double series terminates on a level with and just outside the

outer edge of the peristomial membrane. The teeth are consequently a part of the superficial, not of the marginal series. This arrangement bears a striking resemblance to that found in *Psilaster gracilis* Sladen, but in other respects the two species are dissimilar.

Actinal intermediate plates are confined to a small area in the interrarial region, and extend along the ray as far as the seventh inferomarginal plate. They are arranged in regular series extending parallel with the interrarial line from the inferomarginals to the adambulacrals. Opposite first inferomarginal there are 3 series, abutting against mouth plate and first three adambulacrals; between first and second inferomarginals, 1 series, meeting fourth adambulacrals; opposite second inferomarginal, 1 series of 3 plates meeting fifth adambulacrals; third inferomarginal, 2 series of 3 and 2 plates meeting sixth and seventh adambulacrals; fourth inferomarginal to seventh, a single longitudinal series of plates, the last 2 being rudiments. Actinal intermediate plates are armed with groups of spinelets shorter but otherwise similar to those of the actinal surface of adjacent adambulacrals. Plates frequently bear a spinule in the center, flattened, sharp, and tapering, which resembles those of the ventral series of the proximal inferomarginal plates. In one specimen these are entirely absent, and the spinelets here tend to group themselves into a pedicellarian apparatus. This is true also of many of the actinal intermediate plates of typical specimens.

Madreporic body small, partially obscured by neighboring paxillæ; coarsely striated. It is situated about 3 times its own diameter from the inner border of the superomarginals, and nearly bisects the minor radius.

Color in life: Abactinal paxillar area light dirty green; rest of arms light flesh pink; tube feet raw sienna. Color in alcohol, bleached yellowish or dirty white, brownish on paxillar area.

Young: In an immature specimen in which R=21 mm. and r=6 mm., the superomarginal plates are 13 in number and very massive, almost obliterating the paxillar area of the distal two-thirds of ray. Paxillæ have less numerous spinelets than in the adult, there being about 8 to 10 altogether. Spines of inferomarginal plates of normal number, but shorter than in the adult. Terminal plate with 3 blunt papillæ. Adambulacrals spinelets of marginal series 8 or 9, the new spinelets being added at sides; spinelets of actinal surface in 2 rows. Actinal intermediate plates are fewer in number than in adult, the new plates being added next to inferomarginals and growing along ray, extending in this specimen only as far as fifth adambulacrals. Mouth plates similar to adult, but with fewer spinelets, the teeth being very prominent. Membranous investment of all spinelets relatively thicker than in adult. Another example (R=48 mm., r=9 mm.) is intermediate between the above and adult in nearly all respects except proportions.

Variations: A specimen from station 3887 has rather broader rays than other examples, and the superomarginal plates encroach a trifle less upon the abactinal paxillar area. In another example, from station 4028, the spinules on the actinal intermediate plates are more frequent and longer than in the type. The spines of the inferomarginals are likewise more prominent, there being an additional spine throughout in the superior series; the inferior series extends farther along ray than in normal specimens, and its spinules are more prominent, forming a continuous series with the dorsally placed ones. Still another specimen (station 3995) lacks entirely the usual spines of the actinal intermediate plates, and the spinelets of these plates and of the actinal surface of the adambulacrals are relatively about half as long as those of the type, there being more plates which possess the specially grouped papillæ acting as pedicellariæ. In choosing the type I selected a form which is most representative of the entire series in the totality of its characters.

Measurements of adult specimens of *Psilasteropsis cingulata*, in millimeters.

Major radius .....	95	78	80	77	88	81	93	90
Minor radius .....	18	15	16	15	17	17	18	21
Width of ray between second and third superomarginal plates .....	18	17	17.5	15.5	17.5	16.5	19	20
Breadth of paxillar area, same place .....	12	11	12	10	12	10	13.5	16
Number of superomarginal plates .....	33	30	32	33	33	31	35	30

Localities: Type (no. 21150, U. S. National Museum) from station 3997, off Ūkula Point, Kauai Island, 418-429 fathoms, fine gray sand, brown mud; bottom temperature 41°. Taken also at the following stations, 11 specimens in all.

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
		<i>Fathoms.</i>	
3824.....	South coast of Molokai Island .....	222-498	Coral rock, broken shells.
3887.....	North coast of Molokai Island .....	552-809	Globigerina mud.
3995.....	Vicinity of Kauai Island.....	427-696	Fine gray sand, rocks.
4028.....	do.....	444-478	Gray sand, globigerina.
4123.....	Southwest coast of Oahu Island .....	352-357	Fine gray sand and mud.

This species is most nearly related to *Psilasteropsis patagiata* (Sladen) from off the Cape Verde Islands, from which it may be distinguished by the following characters: The relatively longer and slenderer arms; more strongly tumid marginal plates; absence of incipient pedicellariæ on superomarginals; larger paxillæ, with more numerous spinelets; relatively narrower paxillar area; details of spinulation of inferomarginals; by the adambulacral armature; armature of the mouth plates, the last character showing a resemblance to mouth plates of *Psilaster gracilis*, which, also, is not a typical *Psilaster*.

**Genus DIPSACASTER Alcock.**

*Dipsacaster* Alcock, Ann. N. H., ser. 6, vol. XI, 1893, p. 87. J. Asiat. Soc. Bengal, vol. LXII, 1893, p. 172 (no diagnosis). Type *Dipsacaster sladeni* Alcock.

***Dipsacaster nesiotus* new species.**

Pl. IX, figs. 3, 3a; pl. X, figs. 2, 2a-b; pl. XII, figs. 1, 2.

Rays 5. R=89 mm., r=27 mm. R=3.3 r. Breadth of ray at base, between first and second superomarginals, 30 mm.; between fifth and sixth 25 mm. (See under variations.)

General form flat, depressed; rays tapering arcuately from a broad base to a bluntly pointed extremity. Disk large. Interbrachial arcs wide, well rounded, involving the first few marginal plates. Actinal area subplane. Abactinal area capable of considerable inflation, the paxillar area of rays often arched in such a way as materially to lessen the width of arm. Disk usually more or less inflated, but the integument is quite flexible, and no 2 specimens are alike in this respect. When the abactinal paxillar area is considerably inflated, the animal has a less flattened appearance and the rays appear quite narrow.

Abactinal paxillar area fairly compact, covered with paxillæ arranged on either side of the median radial line in regular obliquely transverse series. These series assume an interradian direction on the disk. On the center of disk and along median radial line no regular arrangement is apparent. Paxillæ are rather large, with a prominent pedicel which is expanded into an irregularly circular or elongated base, and a subglobose crown covered with a compact coordinated group of very many small, delicate, cylindrical, bluntly-pointed, almost capillary spinelets. An average paxilla on a ray would have 30 to 40 of these spinelets, and the larger ones on the disk from 50 to 100. One of the largest paxillæ on the madreporic body has 150. The spinelets are so compactly placed that it is almost impossible to count them accurately. Papular pores are generally distributed and are largest on the lateral portions of the abactinal area; papulæ single. Anal opening conspicuous, surrounded by a membranous periproct. It is situated about 5 mm. from the center of disk. (See p. 1028, Anatomical notes.)

The marginal plates form an angular edge to ray, the inferior series extending laterally beyond the superior and defining the margin of ray. Superomarginal plates are oblong to subquadrate, are slightly arched, and form a conspicuous border to the abactinal area, to which surface they are wholly confined on the ray. In interbrachial arc the plates are oblong, shorter than wide, and their exposed surface stands at an angle of about 45° with the horizontal. On the ray they form a low, slightly arched bevel, and at first glance appear to lie in an almost horizontal plane. Their entire width can be seen when the animal is viewed from above. Superomarginals do not exactly correspond to inferomarginals on outer half of ray, so that the suture between the 2 series follows a zigzag course. Sometimes for a short distance the inferomarginals exactly alternate with the superomarginals. But the number of plates in the 2 series is the same (in type 33). Superomarginals uniformly covered with minute pointed spinelets. In one specimen about 4 enlarged granules, with several of inter-

mediate size, stand in a group in the center of each plate (which is more arched than usual). They seem to form an incipient pedicellarian apparatus. There is a trace of them on a small specimen, but they are evidently absent from 12 others.

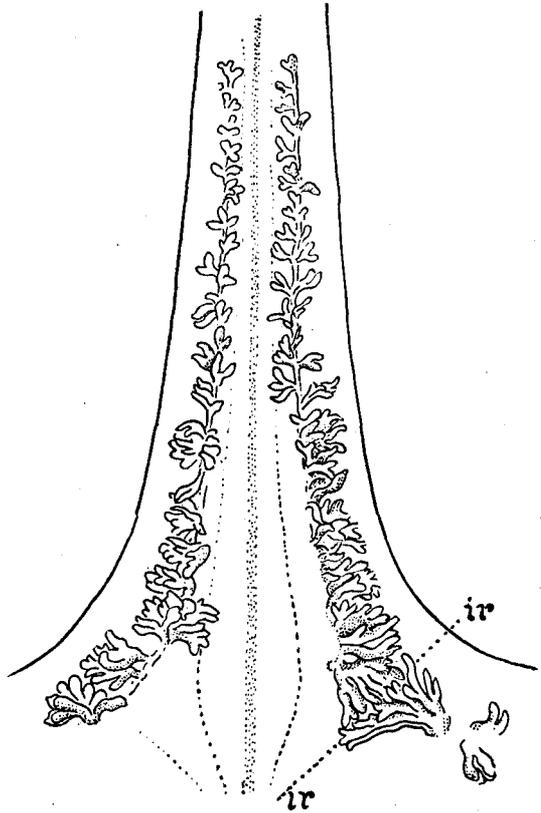
Inferomarginal plates encroach more upon actinal area than do the supermarginals upon the abactinal. They are wider than long, and the outer ends, which extend beyond supermarginals, form each a conspicuous boss armed with a group of short spinules. The plates are tumid along transverse axis, the summit of the elevation being along aboral margin and terminating in the outer armed end. Lateral spinules are slightly flattened, sharp, arranged in 3 close-set, irregular, oblique series on extreme margin of ray, and give a serrated appearance to the margin of arm, each tuft accentuating the tumidity of the abactinal end of its plate. They appear to be simply enlarged members of the numerous sharp squamules covering the general surface of the plate. There are deep fasciolar grooves between the plates of both series.

Adambulacral plates are longer than wide, with a convex margin to furrow, which they overhang. Armature as follows: (1) A furrow series of 7 (sometimes 8) long, stout; much flattened, subacute or blunt, knife-like spines, their bases stout and united by a short web. Their rounded edges are turned furrow-wards, and in respect to the thickness of the blade they taper slightly toward extremity. The blades are broad. Central spines slightly the longer; the outermost spine, at either end of the comb-like series, about two-thirds to three-fourths as long as the succeeding spine. (2) Following the furrow series, and placed so closely that they are pressed usually against it, is an irregular semicircular row of from 3 to 5 unequal tapering spinules, the longest never extending more than two-thirds the length of the adjacent furrow spine. The outer half of the plate bears about 12 to 18 small tapering spinelets similar to those of the actinal intermediate plates. They are arranged either in 2 or 3 irregular longitudinal rows or are scattered.

Mouth plates are rather large, prominent actinally. Armature consists of 9 or 10 large, flattened, blade-like, blunt or truncate spines very much larger than the corresponding adambulacral spines. They form a graduated series, increasing in size toward the inner end

of plate, where they are massive and prominent, the marginal series of 2 companion plates uniting to form, when expanded, a fan-shaped horizontal comb of about 20 teeth. Actinal surface of plate is covered with stout papilliform spinules, very similar on the outer end of plate to those of adjacent ventral intermediate plates. They increase in length toward the inner angle, where there are 2 or 3 spinules considerably larger than the rest.

Actinal interradial areas are large, paved with rather large plates which extend in regular series from inferomarginals to adambulacrals. In a specimen with 39 inferomarginals the intermediate plates extend as a single series as far as the twenty-eighth, or within 15 mm. of the tip ( $R = 84$  mm.). A second series, smaller than that adjacent to the adambulacrals, extends to the fourteenth inferomar-



*Dipsacaster nesiotes*. View of cœlomic side of abactinal surface of one arm, showing arrangement of gonads,  $\times 2$ ; *ir*, interradial line.

ginal, or about one-half the length of ray. A third series extends to the seventh, or one-fifth length of ray. Between first and seventh plates the longitudinal series multiply rapidly. Regarding the plates in series extending interradially, those opposite mouth plates and first 2 adambulacral are irregular. Actinal surface of the plates convex, not raised into an abrupt and prominent keel as in some species of the genus; the convexity is most marked near the inferomarginals. Plates bear a crown of uniform, blunt, papilliform spinelets, often flower-like in appearance. On rays these spinelets tend to become slenderer. Very shallow grooves are present between the plates, roofed over by spinelets.

Madreporic body is very large (7 mm. in diameter) and is situated slightly nearer the margin than midway between it and center of disk. It is concealed by large paxillæ, there being actually on its surface about 18, one of which is much larger than the rest. Outline of madreporic body is subcircular, but the rim is irregularly scalloped.

Color in alcohol bleached brownish or yellowish. Color in life probably deep yellow, but was not recorded.

Young: The smallest specimen of this species ( $R = 18$  mm.,  $r = 7.5$  mm.) differs somewhat from the adult, chiefly in having relatively shorter rays (superomarginals 18) and less prominent inferomarginals. These do not extend conspicuously beyond the superior series, the latter being more arched than in the adult. The inferomarginal spinules are not yet developed, the plate being crowded with rather minute, papilliform, sharp spinelets. Paxillæ have the adult character, but are much smaller. Inferomarginal spinules have appeared in one specimen with  $R = 34$  mm.

Anatomical notes: In this species the gonads extend out into the ray, and are arranged in a longitudinal series on either side of the median radial area, depending from their respective rachides like a row of digitate glands. The largest of the genital tufts is near the interradiial line, and they gradually decrease in size distad, the series ending just beyond the middle of the arm (see text figure). This arrangement of the gonads also obtains in *D. eximius* Fisher, a very distinct species from California, and although not mentioned by the describer, I believe it will also be found to hold true for *Dipsacaster sladeni* and *D. pentagonalis* Alcock. Possibly the group to which *sladeni*, the present species, and that from California belong may be subgenerically different from *pentagonalis*. Judging from the figures, the adambulacral armature of the last species is considerably different from the present species.

The anal aperture opens directly from a single sac-like intestinal cæcum, which lies in the interradial to the left of that occupied by the madreporic body. This sac, the total length of which is about two-thirds the minor radius, has a single small pocket-like branch at one side. A short intestine joins the larger sac with the dorsal stomach. The aperture of the intestine into the sac is very nearly beneath the anus, but is separated from the latter by a broad fold of the wall. Mr. Alcock, in describing *Dipsacaster sladeni* (Ann. N. H., ser. 6, vol. xi, p. 87, pl. v), states that the anal pore is not in connection with the intestine, and includes this as a character of the genus. Inasmuch as the present species is very closely related to *sladeni*, and consequently undoubtedly a *Dipsacaster*, that character can not be regarded as of generic importance.

Superambulacral plates are feebly developed, and do not extend far along the ray. They are apparently absent from the first few ambulacral plates.

Localities: Type (no. 21151, U. S. National Museum) from station 3916, south coast of Oahu Island, 299-330 fms., gray sand and mud; bottom temp., 44°. Taken also at the following stations, in all, 13 specimens:

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
3866.....	Northeast approach to Pailolo Channel, between Maui and Molokai islands.	<i>Fathoms.</i> 283-284	Gray mud, fine sand.
3867.....	do.....	284-290	Fine sand, mud.
3884.....	do.....	284-290	Globigerina mud.
3908.....	South coast of Oahu Island.....	304-308	Fine white sand and mud.
3910.....	do.....	.....	Fine gray sand and mud.

This species is most nearly related to *Dipsacaster sladeni* Alcock. It differs in the marginal plates, which do not correspond on the outer third of the ray, but alternate; in the armature of the infero-

marginals; in the arrangement of spinelets on the actinal surface of the adambulacral plates, and especially in the actinal interradial plates, which are not strongly carinated, as in *sladeni*. The dorsal stomach in *nesiotes* is connected with the intestinal cœcum by a short intestine, but is not in *sladeni*. *Dipsacaster sladeni* was dredged in the Andaman Sea, 250 fathoms.

Genus **PATAGIASTER**, new.

Type *Patagiaster nuttingi*, new species.

General form, character of rays, and disk as in *Dipsacaster*. Marginal plates also similar except that in the interbrachial arcs and on the basal portion of rays the inferomarginal spines form a transverse series instead of being mostly crowded at the abactinal end.

Abactinal surface very compact, the paxillæ much larger than in *Dipsacaster*, more crowded. They are flat-topped and have a central group of about 15 to 40 granules surrounded by a very numerous and regular marginal series of elongated granules, the whole resembling a composite flower. In *Dipsacaster* the paxillæ consist of many capillary spinelets in glomerular tufts on a slender pedicel, and have a quite different facies.

Papular pores absent from median radial portion of rays, and from center of disk. They do not extend beyond the madreporic body any distance toward center of disk. In *Dipsacaster* the papulæ are very numerous and generally distributed.

Actinal interradial areas large. Actinal intermediate plates, adambulacral plates, mouth plates, and their armature essentially as in *Dipsacaster*.

Superambulacral plates present, reduced to the basal half of ray. Anal opening present; connection as in *Dipsacaster nesiotes*. Gonads confined to interradial areas, not forming a longitudinal series along either side of the dorsal integument of ray.

Madreporic body large; hidden by paxillæ as in *Dipsacaster*. No pedicellariæ.

This genus is erected on the strength of the following characters: Distribution of gonads; distribution of papulæ; character of abactinal paxillæ. In these respects it differs from *Dipsacaster*. From *Plutonaster* it differs in respect to the form and armature of the marginal plates, and from *Parastropecten* in the same characters, and in possessing an anal aperture. The last character is of little importance generically. *Parastropecten* is very close to *Leptychaster*.

**Patagiaster nuttingi**, new species.

Pl. ix, figs. 2, 2a; pl. xii, fig. 3; pl. xvii, fig. 1.

Rays 5.  $R=42$  mm.;  $r=14.5$  mm.  $R=2.9r$ . Breadth of ray at base (between first and second superomarginals) 15 mm.

Disk large; rays stout, tapering from a broad base evenly to a pointed but not attenuate extremity. Interbrachial arcs wide and rounded, in some specimens with a slight tendency to become angular. General form depressed and flat, the abactinal area as a rule a trifle inflated; actinal surface plane.

Abactinal paxillar area is very compact and uniform in character, and is covered with close-set paxillæ which are largest along the margin of area and in the interradial areas, where they are arranged in oblique transverse rows. The median radial portion of each arm, and the center of disk, is more or less conspicuously marked off from the above areas, being covered with more crowded paxillæ scarcely more than half as large as those just described. Paxillæ of the central portion of disk are usually slightly smaller than those of the median radial area of rays. Each paxilla consists of a stout pedicel, with a slightly flaring, circular, nearly flat summit, bearing a crown of granuliform spinelets, the centrally situated ones being stouter than the peripheral. The larger paxillæ bear a central group of upwards of 30 or 35, surrounded by a peripheral series of about 25 to 30. The smaller paxillæ of the arms have about 10 granules in the central group, and 15 to 20 in the peripheral series. In specimens from other localities (e. g., station 3836) the paxillæ do not average so large, having 20 to 25 as the maximum number for the central group of spinelets. In these specimens the summit of the pedicel is slightly convex. The bases of all the pedicels are expanded into roundish, irregular, or stellate plates, the last being more prevalent in interbrachial arcs. Papular pores are confined to the area of large paxillæ, i. e., the margin of the abactinal area. They are absent from the median radial portion of rays, and from central portion of disk. Papulæ large, single.

Marginal plates are prominent, forming an angulated margin to ray. Superomarginals, 25 in number from interradiial line to the extremity of ray, are confined to the abactinal surface beyond the interradiial arc, the inferomarginals defining the contour of ray. They are subquadrate in the outer half of arm, but oblong in interbrachial arc, and form a low, slightly arched bevel to abactinal area. They are uniformly covered with papilliform granules which are very regular and resemble the central granules of papulae, but are larger. Deep and narrow fasciolar grooves separate the exposed surfaces of consecutive plates, the granules covering them being slightly slenderer than the others.

Inferomarginal plates correspond with the superomarginals, and extend laterally beyond them, all this portion being the specialized ridge of the plate. The fasciolar grooves are therefore, as in *Dipsacaster*, very deep and narrow. Outer end of each plate is slightly tumid, the appearance being accentuated by the tufts of spinules. The first 4 to 6 plates bear a transverse series of 3 or 4 short, stout, tapering, flattened, sharp spinules. The other plates usually bear 2 such spinules in an oblique series on the abactinal end of the plate, but laterally. Considerable variation exists as to the number of these spinules. They are sometimes reduced in size and crowded toward the upper end of the plate (i. e., on first 4 or 6 plates) and the inner spinule is often spaced from the other 2 or 3. The general surface of the inferomarginals is covered with pointed squamiform granules which are enlarged in the neighborhood of the spinules to form a small tuft. On the abactinal surface of the plate the granules are similar to those of the superomarginals, and in the fasciolar grooves they are slender or spinuliform or capillary.

Adambulacral plates are slightly longer than wide on the rays, shortening near the mouth plates. Furrow margin convex. Armature as follows: (1) A furrow series of 7, 8, or 9 long, slender, compressed, bluntly pointed spinelets, radiating only slightly. The tips form a convex edge to the comb. The lateral spinelets are often conspicuously shorter than the others. (2) On the ray the actinal surface of each plate bears 8 or 9 shorter tapering spinelets, disposed usually in 2 semicircular rows, those of the series nearest furrow series the longer. There are besides 3 to 5 still smaller spinelets along both adoral and aboral edge of plate, extending over the grooves which separate the plates. These grooves are continuous with those passing between the actinal intermediate plates, which in turn communicate with the much deeper furrows between the exposed surfaces of marginals. The spinelets are not webbed, however. The first 3 or 4 adambulacrals possess fewer furrow spinelets (6 or 7) because the plate is shorter. The actinal spines are less crowded (15 to 23) and are arranged in a rather definite series along both adoral and aboral margins, with 2 intermediate transverse or obliquely transverse series. The first longitudinal actinal series is sometimes well defined on the plates. Many variations in arrangement occur.

Mouth plates are prominent actinally, fairly large, the exposed surface curving strongly dorsad toward the mouth. Armature consists of a furrow series of 8 tapering, long, slender spinelets, bluntly pointed and increasing in length toward the inner angle. The inner spinelets are slightly flattened and are usually turned away from the mouth, but the outer members of the series extend about halfway to the outer end of plate, to which the series is continued along the margin adjacent to first adambulacral as a row of much smaller, slenderer, spinelets (8 to 10 in number). Actinal or exposed surface bears a series of slender, tapering, bluntly pointed spinelets along margin of suture. On the mouth angle these are about as long as adjacent marginals, but rapidly decrease in length as they proceed outward, becoming short and round-tipped. On outer half of each plate an intermediate, subparallel, and similar series is present, often, however, arranged irregularly, so as to give the appearance of 2 intermediate series. Spinelets of mouth angle usually appear crowded or bunched together.

Actinal interradiial areas fairly large, paved with close-set roundish plates, which extend nearly halfway to tip of ray (to ninth inferomarginal plate). These plates are arranged in series extending from inferomarginals to adambulacrals, and those plates adjacent to the latter are larger than the others. When viewed from the surface toward body cavity, the plates are seen to be imbricated, the outer end of each being slightly elongated and overlying the inner rounded end of the adjacent plate. Regarded from the actinal surface, it is the inner end which overlies the outer. On the rays this inner end is somewhat elongated, and the series adjacent to the adambulacrals slightly overlaps the outer margin of the latter. Central portion of each plate is raised into a regular paxillar tabulum with a convex summit, surmounted by a radiating central group of 6 to 10 short, rounded, subconical, pointed or blunt-tipped, granuliform spinelets, with a peripheral series of about the same number of slender, slightly longer spinelets placed at a lower level on the pedicel or tabulum. Often the central and

peripheral series are nearly alike and form a coordinate group. Fairly well defined channels run between the series of keels or pedicels, interradially from inferomarginals to adambulacrals.

Superambulacral plates are feebly developed, scarcely more than rudiments, the series extending about one-half length of ray, and absent from innermost 4 to 6 adambulacrals. They appear to be better developed in medium-sized than in fully adult specimens.

In this species the gonads are clustered on either side of the interradial line and do not extend as a longitudinal series along either side of the medio-radial line far into the ray, as in *Dipsacaster nesiotis*.

Madreporic body is fairly large, nearly hidden by paxillæ; irregular in outline; striations radiating. Situated slightly nearer to margin than midway between margin and center of disk.

Color in life: Abactinal paxillar area coral red over area occupied by small paxillæ, becoming duller or grayish coral red at the sides; actinal surface creamy white; marginal plates the same, tinged with pink. Color in alcohol, brownish yellow to ashy white.

Young: The smallest specimen taken measures R 12 mm., and r 5 mm., and in general appearance is very like the adult. The difference is a lack of enlarged spinules on inferomarginal plates. The interradial areas are already well developed, and paxillar area is compact as in adult. Another specimen of nearly the same size possesses a single enlarged spinule on the edge of the ray.

Localities: Type (no. 21152, U. S. National Museum) from station 4081, north coast of Maui, 202-220 fathoms, gray sand and foraminifera; bottom temperature, 51.7°; abundant. Taken also at the following stations, in all 414 specimens.

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
		<i>Fathoms.</i>	
3836.....	South coast of Molokai Island.....	238-255	Brownish gray mud and sand.
3919.....	South coast of Oahu Island.....	257-220	Gray sand.
4044.....	West coast of Hawaii Island.....	233-198	Fine gray sand.
4082.....	North coast of Maui Island.....	220-238	Gray sand.
4083.....	do.....	238-253	Do.
4115.....	Northwest coast of Oahu Island.....	195-241	Coral sand, foraminifera.
4116.....	do.....	241-282	Do.
3472.....	South coast of Oahu Island.....	295	Fine white sand.

This species is found, therefore, at a depth of about 250 fathoms and apparently does not range much over 30 fathoms either side of this average. It was taken on a special line of dredgings north of Maui which were made for the purpose of determining vertical distribution.

The chief differences between this and the foregoing species have already been pointed out. The present form is in some respects intermediate between the *Astropectinidæ* and *Plutonasteridæ*.

The species is named for Prof. Charles Cleveland Nutting.

Family LUIDIIDÆ Verrill, 1899.

Luidiidæ Verrill, revision of certain genera and species of starfishes, with description of new forms. <Trans. Conn. Acad., vol. x, 1899, p. 201. Equivalent to Luidiinae Sladen, Challenger Asteroidea, 1889, p. 244.

Genus LUIDIA Forbes

*Luidia* Forbes, Mem. Wern. Soc., vol. VIII, 1839, p. 123.

*Key to Hawaiian species of Luidia.*

- a. Rays more than 5, mottled with brown.
  - b. Pedicellariæ very few; abactinal paxillæ rounded, with one or two prominent spinules; adambulacral spines 4. No inferomarginal pedicellariæ..... *hystrix*.
  - bb. Pedicellariæ numerous, conspicuous, 2 to 4 between inferomarginal and adambulacral spines; the latter 3 in number. Inferomarginal plates, with 2 to 4 pedicellariæ..... *magnifica*.
- aa. Rays constantly 5.
  - b. Prominent lateral spines to ray..... *Luidia* sp.
  - bb. No prominent spines on ray..... *brevispina*.

*Luidia hystrix*, new species.

Pl. xiii, figs. 1, 2; pl. xiv, figs. 1, 2; pl. xvi, figs. 2, 2a.

Rays 8. R = 195 mm. (longest ray, the shortest R being 178 mm.) r = 19 mm. R = 10.2 r. Breadth at widest part near base 20 mm.

Rays very elongate in proportion to disk, slightly swollen above base, and thence very gradually tapering up to the bluntly pointed extremity; robust, depressed, with well-rounded sides. Abactinal surface more or less flattened on disk; convex on rays, but flattened or even slightly concave along median radial line. In young specimens rays are always strongly convex above. Actinal surface rounded, the ambulacral furrow broad and tube feet very large, with conical sucking disks.

Paxillæ of abactinal area large, crowded on disk, and there without definite arrangement. They are arranged in definite, spaced, longitudinal rows along rays, except in a narrow median radial area, where they are more crowded and not so regular. On either side of this median radial area one can count 6 regular longitudinal series of paxillæ on the basal portion of ray and 5 over the remainder. Paxillæ are rotund to slightly subquadrate at the margins of area. Nearly all paxillæ of rays except the series adjacent to inferomarginal plates and those of distal portion of median radial area bear a robust, upright, tapering sharp thorn or spinule, about 2 to 2.4 mm. in length, placed in center of tabulum; those of the median radial area (proximal portion) are shorter (1.5 mm.). This spinule is surrounded by 5 to 8 or 10 robust, cylindrical or clavate, obtusely tipped, papilliform spinelets, placed also on the tabulum. External to these on the periphery of tabulum are 15 to 25 (usually about 17 or 18) slender papilliform spinelets, usually somewhat irregular in thickness. Paxillæ of the series adjacent to marginal plates are very slightly smaller than the others and lack the central spinule. Not infrequently paxillæ of the regular spinulated series also lack the spinule, but in other respects they resemble the spinopaxillæ. Occasionally paxillæ of disk bear a short conical spinelet, but most of them have instead 8 or 9 cylindrical flat-topped granuliform spinelets in the center of tabulum, surrounded by a peripheral series of 20 to 25 much slenderer ones.

Inferomarginal plates are very numerous, short, and wide, each with a special raised ridge, between which are deep fasciolar grooves. Plates bear, along the median line, a transverse series of 4 or 5 (rarely 6) long, slightly curved, very sharp, rather delicate spines. These increase in size toward outer edge of plate, the inner 2 being usually much smaller than the outer 3, the median spine of which is longest. Toward base of ray there is less difference between the inner and outer spines, although the inner 2 are always much smaller. The elevation or keel of the plate, upon which the spines are borne, is bordered by long, slender spinelets, a few standing on the exposed surface, between the spines. Sides of fasciolar grooves are covered with capillary spinelets.

Adambulacral plates are wide, but short, as seen on the actinal surface, and are united by broad bands of integument. The armature, which is borne on a sort of keel, consists of 4 spines, of which 3 form a regular transverse row, the median being longest and furrow spine shortest. The fourth spine is situated between the outer two, but adorally and out of line with the series. Near base of ray a fifth spine is added to outer end of regular series, and sometimes a smaller spinule stands in line with the odd spine, which is about the length of the furrow spine or shorter. Furrow spine is slightly curved, compressed, and saber-like. The outer spines are faintly curved at the base, are tapering, bluntly pointed, and usually directed away from the furrow. External to the outermost spine, about midway between it and the innermost inferomarginal spine, is a radiating group of 8 or 9 ciliary spinelets of different sizes. In the midst of these there is sometimes an inconspicuous 3-jawed pedicellaria, fairly wide at base, but with tapering, bluntly pointed jaws, scarcely one-third the length of adjacent adambulacral spine. These pedicellariae, of which there is never more than one to a segment, are not numerous, being present on about half the adambulacrals of some arms and almost absent from others.

Mouth plates are long and narrow. Along the margin are about 8 long, slender, pointed spines, which increase in length toward the inner end of the plate, the innermost spine being longest, flattened, and directed toward center of actinostome. The adjacent spine is also frequently flattened. Parallel with this series, and close to it, on actinal surface, is another series of 4 similar spines. Frequently this second series is more or less irregularly grouped in with the first. True marginal spines are found on side of plate, one near base of the big inner spine, and 3 or 4 in a cluster, considerably higher up, about midway between the first and the roof of the furrow.

Actinal interradial areas small; there are apparently about 4 plates, each bearing a tuft of long slender spinelets surrounding a central spine.

Madreporic body hidden by paxillæ.

Color in life: Above, cream color, mottled with burnt sienna and chocolate; below, white. Spines white. Ambulacral feet whitish, with sucking disks of orange yellow. In young individuals the chocolate color tends to form 3 cross bands on arms, a broad one near tip, one about the middle of ray, and the third at base; the last connects with an indefinite ring of mottling about disk. Center of disk brown.

Young: In very young individuals the abactinal spinules are entirely absent, as might be expected. The smallest specimen has  $R=15$  mm., and  $r=6.5$  mm.; 10 rays. Another young specimen, slightly larger, has a smaller disk and 8 rays. In the young the inferomarginal and adambulacral spines are relatively smaller than in the adult, the outermost spine of the former series being the largest, the remainder quite insignificant. Pedicellariæ are entirely absent. In a specimen with  $R=73$  mm., the abactinal spinules have appeared on all the series of paxillæ, upon which they are present in the adult; but the spinules are much smaller than in the fully adult. Judging from a slightly smaller specimen than this, the spinules appear first on the innermost regular series of paxillæ, and thence spread over the rest, never appearing on the marginal row. Most of the regular series have subquadrate paxillæ, which become more and more rounded toward median radial line. The inferomarginal spines are practically like those of the adult, the innermost 2 being a little weaker. On these intermediate specimens the adambulacral armature is as in the adult, except that pedicellariæ are very much less numerous.

Localities: Type (no. 21153, U. S. National Museum) from station 3876, Auau Channel, between Maui and Lanai islands, 28 to 43 fathoms, sand and gravel; bottom temperature, 74°. Taken also at the following stations, 11 specimens in all:

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
		<i>Fathoms.</i>	
3861.....	Pailolo Channel .....	30-52	Fine sand, small pebbles, coral.
3987.....	Southeast of Kauai Island .....	55-60	Coral fragments, coarse coral sand.
4031.....	Penguin Bank, south of Oahu Island .....	27-28	Coral, fine coral sand, foraminifera.
4032.....	do.....	27-29	Do.
4034.....	do.....	28-14	Do.
4168.....	Vicinity of Bird Island .....	20-21	Coral sand, foraminifera.

This species is most nearly related to *Luidia aspera* Sladen, taken by the Challenger Expedition off Samboagan, and Tablas Island, Philippine Group, and north of Admiralty Island, the vertical range being 10 to 150 fathoms. Both species are related to *Luidia maculata* Müller and Troschel, as well as to the following species, *Luidia magnifica*. *Luidia hystrix* differs from *aspera* in the character of the adambulacral armature and abactinal paxillæ. In *aspera* only 3 inner rows of paxillæ are spiniferous. Our species has an extra spine to the adambulacral armature, and fewer pedicellariæ, there being never 2 between the inferomarginal and adambulacral spines as in *aspera*.

A young specimen was found to have engulfed a young sea-urchin and a small colony of polyzoa.

***Luidia magnifica*, new species.**

Pl. xv, figs. 1-3; pl. xvi, figs. 1, 1a.

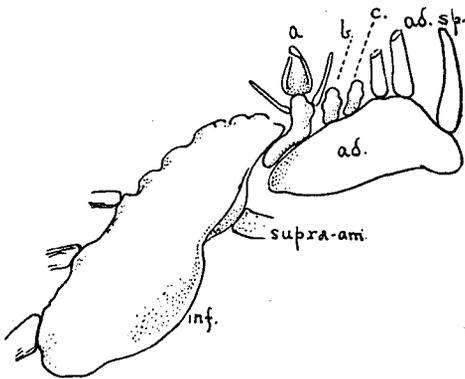
Rays 10.  $R=330$  mm.;  $r=41$  mm.;  $R=8r$ . Breadth of ray at widest part, near base, 37 mm. The outer third of the two unbroken arms has been regenerated, and although they are nearly the diameter of basal portion, they are probably considerably shorter than in life.

Rays very elongate in proportion to disk; considerably wider about 30 mm. from base than directly at junction with disk. They taper very gradually to a bluntly pointed extremity, and are robust, depressed, with well rounded sides. Abactinal surface capable of inflation, but flattened on disk; convex on rays, but flattened or even slightly concave along median radial area. Actinal surface with rounded borders. Ambulacral furrow wide, the tube feet very long, with comparatively small, ovoid sucking disks. Pedicellariæ very numerous on actinal surface.

Paxillæ of abactinal area are large, roundish on disk, and very crowded; on rays arranged in 6 regular longitudinal series at either side, becoming reduced to 5 on outer part of ray. In these regular series the paxillæ are very sharply quadrate, but over a fairly wide median radial area they are rounded in outline, considerably smaller than those of the regular series, are crowded, and have no definite arrangement. At base of ray paxillæ of all 6 longitudinal rows bear a tapering, sharp, stout, often slightly curved spinule or thornlet, those on innermost series longest (2 to 4 mm.), thence decreasing in size toward margin, being usually quite short on outer 2 rows. On outermost of marginal series (corresponding to the aborted superomarginal plates) there is now and then a central spinule as long as any of the innermost series. On outer part of ray beyond middle there are about 3 definite longitudinal rows of spinules. The spinule is borne usually near inner edge of quadrate tabulum, or near the aboral inner corner, seldom in the center. Exposed surface of tabulum is only slightly convex, and bears 20 to 25 stout, subclavate, papilliform spinelets, which become much heavier, rather flat-topped, and granuliform toward the center, where they often have the appearance of being bent the same way that the spinule is directed—namely, diagonally toward inner aboral corner of plate. Periphery of tabulum bears a series of numerous, blunt, much slenderer spinelets. Paxillæ of median radial areas and disk lack enlarged spinule, are roundish, and smaller. The central group of spinelets is also more regular, increasing in size toward the center, where they are rather

flat-topped, clavate, and granuliform, resembling the large end of an apothecary's pestle in miniature.

Inferomarginal plates very numerous, short, and comparatively wide, each with a special ridge, separated from that adjacent by an unusually deep and wide fasciolar groove. Armature consists of a transverse, regular series of 5 or 6 spines, of which the outer 2 or 3 are longer than the inner. The former are long, slender, tapering, very sharp, and slightly curved. Three is the most frequent number; the longest (7 to 9 mm.) is sometimes the outer (when there are but 2 enlarged lateral spines), sometimes the median, but there is little difference in the length of the three. The inner 2 or 3 of the group of 6 are often augmented by several auxiliary spinules. This group is less regular than the outer spines, the spines being much smaller, tapering, with usually an expanded, flat, chisel-like tip. The plate is fringed by stout pointed spinelets, of considerable size, which are also scattered over surface of plate between the large spines. Here



*Luidia magnifica*. Inferomarginal and adambulacral plates, removed to show actinal intermediate ossicles (a, b, c). ad., Adambulacral plate; ad. sp., adambulacral spines; inf., inferomarginal plate; supra-am., supraambulacral plate (end only),  $\times 4$ .

they are unequal in size, and irregular in distribution. In addition there is 1 (or rarely 2) 3-jawed pedicellaria between the large lateral spines, making 2 or 3 for each plate. These pedicellariæ, which are not to be confused with the larger ones, found in the interval between the adambulacral and innermost inferomarginal spines, are sessile, with a fairly broad base and blunt tip, being roughly conical.

Armature of adambulacral plates, which is borne on a transverse keel, consists of 3 spines, placed one behind the other, the median longest. Furrow spine flat, saber-like, and bluntly pointed. The next two are close together, and separated from furrow spine by an interval. They are long, straight, tapering, round tipped, and usually bent away from furrow. An inconspicuous, short, blunt, flat papilla is situated on adoral side of base of outermost spine. External to the latter, between it and inferomarginal spines, is a row of 3 (occasionally 4, or at end of ray 2) large 3-jawed pedicellariæ, which increase in size outward, the outermost being situated on a slightly greater prominence than the others. The innermost is situated just external to the outermost adambulacral spine, and reaches nearly halfway to top of this. Each pedicellaria is perched on the top of a discrete ossicle shaped very much like the shaft of a paxilla. The inner 2 (b, c, see fig.) rest on the surface of the adambulacral plate, but the bottom of the outermost and largest is bent, and is wedged between the adambulacral and inferomarginal, representing the usual actinal intermediate plate, evidently. These ossicles are immersed in muscle, and are not readily comprehended unless treated with hot caustic potash. They represent really 3 longitudinal series of actinal intermediate plates, something very unusual for this

genus. Each pedicellaria, perched on the knob-like tip of its ossicle, is surrounded by a circle of 5-10 papilliform spinelets of unequal lengths, the longest often reaching nearly to tip of pedicellaria. The latter has a rather broad base, with bluntly tipped jaws, which are about  $1\frac{1}{2}$  to 2 times as long as the extreme width of base. These jaws are often slightly twisted at tips, like the opening bud of a flower, which indeed the pedicellaria somewhat resembles, the similarity being increased by the calyx-like circlet of spinelets already mentioned. The outermost pedicellaria of this group is always largest, being usually, exclusive of its pedicel-like base, 1.5 to 2 mm. long.

Mouth plates long and narrow. The 2 inner angle spines are long, flat, round-tipped or subtruncate, much stouter than any others of the plate, and directed toward center of actinostome. The true furrow-series is continued toward the end of first ambulacral plate, in about 3 groups, each of 2 papilliform spinelets. One of these spinelets, adjacent to the tooth, is enlarged, flattened, about half as long as tooth. Extending along margin of actinal surface of plate is an irregular series of long spines, tapering and slender, and often slightly flattened at tip. They decrease in size toward outer end of plate, where there is also a marginal fringe of spinelets, extending inward along side of groove adjacent to first adambulacral. The superficial series might be regarded as 2 irregular series on the outer part of plate. Actinostome large.

Actinal interradiar areas practically absent, the adambulacrals of adjacent rays with their large pedicellariæ touching each other.

Madreporic body entirely hidden by paxillæ.

Color in alcohol, yellowish brown, mottled with darker; in life probably similar to the foregoing species.

Locality: Type (no. 21154, U. S. National Museum) from station 3849, south coast of Molokai Island, 73 to 43 fathoms, coarse sand, broken shells, coral; 1 specimen.

This very distinct species is related to *Luidia maculata* and *Luidia aspera*, as well as to the foregoing species. From the last 2 it differs particularly in the character of the adambulacral armature and in the presence of 3 longitudinal series of actinal intermediate ossicles, and probably also from *maculata* in these respects. I have been obliged to rely upon the original description of *maculata* (System der Asteriden, p. 77), which is none too satisfactory, and upon the critical remarks of Perrier (Révision des Stellérides, p. 338). So far as I am aware, no one has figured *maculata*, the type of which came from Japan. Neither Müller and Troschel nor Perrier mention abactinal spines or the pedicellariæ of the inferomarginal plates, so I am forced to conclude that these are not present on *maculata*. Nor is it clear from the original description whether the large actinal pedicellariæ follow the adambulacral spines or are among them. Perrier says they follow the spines, while Müller and Troschel state that they are among or between [zwischen] them. While *magnifica* differs from *aspera* in the same respects as from *hystrix*, it may not be amiss to detail some of the differences which separate it sharply from *maculata*.

*Luidia maculata.*

- No enlarged spinules on abactinal paxillæ.
- Adambulacral armature consisting of one furrow and 3 or 4 actinal spines.
- Pedicellariæ slender, 3-4 times as long as broad.
- A single series of actinal intermediate ossicles.
- Inferomarginal spines 2-3, the innermost longest.
- No pedicellariæ on inferomarginal plates.

*Luidia magnifica.*

- Four to 6 lateral series of abactinal paxillæ with enlarged spinules.
- Adambulacral armature of 1 furrow and 2 actinal spines.
- Pedicellariæ  $1\frac{1}{2}$  to 2 times as long as broad, 3 in number, in a definite series external to adambulacral spines.
- Two to 4 series of actinal intermediate ossicles, each ossicle bearing a pedicellaria.
- Inferomarginal spines about 5, the outermost longest; the inner 2 with flattened chisel-shaped tips.
- Three or sometimes 2 or 4 pedicellariæ on inferomarginal plates between the large lateral spines.

The inferomarginal plates of this form are relatively rather small. The actinal intermediate ossicles are aberrant also. The interval between successive segments of the ray is comparatively very large, and filled with muscle. This fact, combined with the arrangement of actinal plates, gives a great degree of flexibility. Professor Verrill, to whom I sent a portion of an arm for inspection, writes that he believes this species can swim rapidly, using its large ambulacral feet as paddles, as he has seen *Luidia clathrata* do. The tube feet are very large.

This is a remarkably large species. The type, if perfect, would measure over 2 feet in diameter. It is thus nearly as large as a specimen of *L. savignyi*, with 9 arms, recorded from Mauritius, the shortest ray of which was 350 mm., the longest 370. Prof. F. J. Bell has referred to this specimen as the largest starfish on record.<sup>a</sup>

**Luidia sp.**

In the collection there is a single specimen of a young *Luidia*, which can not be positively determined on account of its small size. R=20 mm.; r=4 mm. R=5r. Rays 5, very gently tapering; abactinal area convex. Paxillæ are arranged in 4 regular rows at either side of arm. These would apparently have become subquadrate. Those of median portion of arm are round and likewise rather regularly arranged. Inferomarginal plates with a single, prominent, slender, slightly flattened spine, about as long as width of plate, forming a series along margin of ray. Actinal surface of plate with numerous slender spinelets, but none large enough to form a companion spine. Adambulacral armature consists of a long, slender, flattened, slightly curved furrow spinelet, and 2 actinal spinelets in a regular transverse series, besides 1 or 2 shorter spinelets situated adorally to the latter. Occasionally a long 2-bladed pedicellaria takes the place of one of these latter spinelets, but as yet pedicellariæ are rare. The dredge-station record is missing, but the specimen was probably taken from Penguin Bank, south of Oahu, in a depth of about 25 fathoms.

This specimen appears to belong to an undescribed species very closely allied to *Luidia forcificifer* Sladen, from Torres Strait, 6 fathoms, and the Arafura Sea near entrance to Torres Strait, 28 fathoms. (Sladen, Challenger Asteroidea, p. 260.)

**Luidia brevispina** Lütken.

*Luidia brevispina* Lütken, Fortsatte kritiske og beskrivende Bidrag til Kundskab om Søstjernerne. <Videnskabelige Meddelelser, 1871, p. 288. Perrier, Révision des Stellérides, 1875, p. 337.

This species is recorded by Perrier (l. c.) from the Sandwich Islands, where 9 specimens were collected by Mr. Ballieu, and received by the Museum d'Histoire Naturelle de Paris in 1876. No examples were secured by the Albatross Expedition.

**Family PSEUDARCHASTERIDÆ Fisher, 1905.**

Pseudarchasterinæ Sladen, Challenger Asteroidea, 1889, p. 109; emended. Verrill, Trans. Conn. Acad., vol. x, 1899, p. 187. Astrogoniinae Perrier, Exped. Scientif. Travailleur et du Talisman, Echinodermes, 1894, pp. 337, 338. Pseudarchasteridæ Fisher, Bull. Bureau of Fisheries, vol. xxiv, 1904 (1905), p. 303.

**Genus PSEUDARCHASTER Sladen.**

*Pseudarchaster* Sladen, in Narr. Challenger Exped., vol. i, 1885, p. 617.

*Astrogonium* b Perrier (non Müller and Troschel) Exped. Scientif. Travailleur et du Talisman, Echinodermes, 1894, p. 338.

*Key to Hawaiian species of Pseudarchaster.*

- a. Rays shorter; no enlarged spinules on the actinal intermediate plates..... *myobrachiua*  
 aa. Rays longer; enlarged spinules on the actinal intermediate plates..... *jordani*

<sup>a</sup> Bell, Ann. N. H., ser. 6, vol. III, 1889, p. 222.

<sup>b</sup> The substitution of the name *Astrogonium* for *Pseudarchaster* Sladen is wholly unnecessary and unwarranted. *Astrogonium* was first proposed by Müller and Troschel (System der Asteriden, 1842, p. 52) and included 4 genera—*Hippasteria* Gray, *Goniaster* Agassiz, *Pentagonaster* Gray, and *Tosia* Gray—all of which are now recognized and in current use. The genus was thus a composite group without a definite type. In 1847 and 1866 Gray used the name in a more restricted sense, including forms now referred to *Tosia* (or to *Pentagonaster*, according to the point of view), such as *Tosia granularis* (Retzius), and to the *Odontasteridæ*, as *Acodontaster militaris* (Gray) Verrill. If it were used at all it would be applied, with very questionable propriety, to the group containing the *Asterias granularis* of Retzius, which belongs to the previously described *Tosia*. But as *Astrogonium* was an artificial group, a synonym of, say, *Hippasteria*, or of any one of the other 3 above-mentioned genera, the name should be discarded for all time, on the ground of "once a synonym, always a synonym."

However, in 1889 Sladen incorrectly restricted *Astrogonium* to Gray's genus *Pentagonaster*.

Perrier in 1894 transferred the name to an entirely different group, one unknown to either Müller and Troschel or Gray, namely, to *Pseudarchaster*+*Aphroditaster* Sladen. Both of these names are perfectly tenable, and the course of Perrier is wholly contrary to the most widely accepted laws of nomenclature. *Astrogonium* has been used by several authors since 1894 in place of *Pseudarchaster*, the correct name of the group. (See Verrill, Trans. Conn. Acad. xx, 1899, p. 149.)

*Pseudarchaster myobranchius*, new species.

Pl. x, figs. 6, 6a; pl. XIX, 1, 1a-c.

Rays 5.  $R=34$  mm.;  $r=13$  mm.  $R=2.61r$ . Breadth of ray at base, between second and third superomarginal, 12 mm.; halfway to tip, 7 mm.

Rays rather narrow and short, slightly tapering after the basal expansion to a pointed extremity. Interbrachial arcs wide and well rounded, so that base of rays is broad. Margin of rays evenly rounded, more beveled on disk.

Abactinal paxillar area compact and uniform; very narrow on rays, consisting of only three rows of plates on outer half, where it is less than half as wide as a superomarginal. Paxillæ roundish to subpolygonal, close-set, and not arranged with any great regularity. The pedicel is surmounted by 12 to 18 coordinated, short, truncate, 3- or 4-sided spinelets, prismatic in appearance. A few of the peripheral spinelets are usually noticeably smaller than others. Paxillæ decrease in size toward margin and on rays, where there is usually only 1 central spinelet with 7 to 9 surrounding it. A well-defined groove is present between the paxillar area and marginal plates. Papulæ absent from distal half of ray.

Superomarginal plates, 23 in number from median interradial line to extremity of ray, form a broad, conspicuous margin to abactinal area. Length in interbrachial arc less than on ray (except outer fourth). Plates are covered with a close polygonal granulation, the granules increasing in size and becoming less crowded toward outer end of plate. A marginal series of much smaller granules surrounding each plate is clearly distinguishable. Plates of outer half of arm have an oval naked spot on middle of dorsal aspect. This area begins on ninth or tenth superomarginal and is present on 9 or 10 plates. The last (distal) few plates, being very small, are completely covered with granules.

Inferomarginal plates correspond in number to superomarginals, and encroach rather more upon actinal area than do the latter upon abactinal. Plates in interbrachial arc are conspicuously shorter than those on ray. They are covered with numerous granules, which increase conspicuously in size toward outer margin of plate. Most of the granules are flat-topped, roundish, or polygonal, but many show a tendency to become squamiform. Plates of interbrachial arc bear a median transverse series of 4 flattened, tapering, sharp spinelets which have a swollen base and are closely appressed to the plate. These are reduced in number to 3 and 2 on ray, and finally to one on outer part. The series is well spaced.

Adambulacral plates have an angular furrow margin, the apex of which is nearer adoral than aboral side. The armature consists of a furrow series of 6 or 7 short, roundly truncate, flattened spinelets, 4 of which are on that side of the angular margin turned away from mouth, the longest spinelet at apex, and the other 2 on the adoral side of the margin. They thus form a palmate series and are graduated in length. Furrow series is continued along adoral margin in 2 to 5 gradually shortening spinelets, and similarly along the aboral margin in 2 or 3 spinelets. In middle of actinal surface there is an erect tapering spinule, more prominent than any others of plate, and clustered around it are numerous small, papilliform spinelets, especially toward the outer side of plate. On first few plates the prominent spinule is not present. The spinelets which are found along the adoral and aboral margins of each plate are opposed over a sort of fasciolar furrow between the plates.

Actinal intermediate plates are subquadrate or roundish, large, and do not extend beyond the third inferomarginal. They are arranged in about 3 series parallel to the adambulacrals, and increase in size toward disk. They are covered with round papilliform granules, which are truncate, well spaced, and often arranged in more or less definite rows. No fasciolar grooves are present between the plates, or if present can not be regarded as in any manner specialized.

Mouth plates are large, ovoid, and prominent actinally, with an extensive furrow margin. The armature consists of a furrow series of 7 blunt flattened spinelets, similar to but larger than the adambulacral furrow spinelets, increasing in length toward inner end of plate. These inner spinelets are slightly compressed in an interradial plane, and likewise taper a trifle. A superficial series of 10 is present along the margin of the median suture, decreasing in length toward the outer end of plate, the outermost being scarcely more than flat-topped granules. Furrow series is continued along margin adjacent to first adambulacrals in about 6 short, graduated, very flat spinelets, opposed to those of the adjacent edge of adambulacral. Between these and superficial series is a row of 3 or 4 small papilliform granules, similar to the adjacent superficial series.

Madreporic body is very small, situated halfway between center of disk and inner edge of superomarginals; entirely hidden by paxillæ.

Color in alcohol, dull brown.

Young: Two young, apparently of this species, were taken at station 4028.  $R=8.5$  mm.;  $r=5$  mm. (smaller specimen). They differ much from the adult in general form, having short, stout rays. Each of the broad superomarginal plates (8 in number from median interradiial line) has a naked area on the abactinal surface, similar to that of the adult except that in the young these extend around the interbrachial arc. Enlarged spinules of inferomarginals are present (absent on other specimen, however), but much reduced. Actinal intermediate plates are very few, and the actinal spinule of adambulacrals is not yet larger than the others. Furrow spinelets of adambulacrals 4 to 6.

Locality: Type (no. 21158, U. S. National Museum) from station 3995, vicinity of Kauai, 427-676 fathoms, fine gray sand and rocks; bottom temperature, 40.6°. Two young specimens were taken also at 4028, southwest coast of Kauai, 444-478 fathoms, on gray sand and globigerina.

This species is distinguished by its short rays, broad marginal plates, very narrow abactinal paxillar area on rays, small actinal intermediate area, the plates of which are devoid of spines and of specialized fascioles between them, and by the enlarged spinule on the adambulacrals plates. The madreporic body is entirely hidden. The species is thus very distinct from any Pacific form, and would seem to approach nearest to *Ps. tessellatus* Sladen from Cape of Good Hope, from which, however, it is readily distinguishable by the shorter rays, broader marginal plates, with naked areas on superior series, by the hidden madreporic body, and by the absence of spinules from actinal intermediate areas, where the granulation appears also much less compact.

***Pseudarchaster jordani*, new species.**

Pl. x, figs. 7, 7a; pl. xix, figs. 2, 2a.

Rays 5.  $R=52$  mm.;  $r=16.5$  mm.  $R=3.15$  r. Breadth of ray at base, between first and second superomarginals, 18 mm.

Rays moderately long, robust, tapering continuously from a fairly wide base to a pointed extremity. Interbrachial arcs not so wide as in preceding species; rounded. Abactinal surface a trifle inflated over radial areas, and slightly sunken along interradiial lines.

Abactinal paxillar area is compact, not so narrow on rays as in preceding species. In the middle of  $R$  there are 5 longitudinal rows, the area here equalling in width one of the adjacent superomarginal plates. The paxillæ are relatively larger than in *Ps. myobrachioides*, and are arranged with beautiful regularity in a radial and numerous parallel series, the plates decreasing in size toward margin. They are also smaller in an apical area, inside the primary radials. A radial paxilla consists of about 10 to 12 hexagonal or prismatic, granuliform spinelets placed on the convex summit of the pedicel, surrounded by a peripheral series of 15 to 18 smaller, unequal, slightly flattened ones which are considerably slenderer and do not form a regular series. The smaller paxillæ differ only in having fewer spinelets. Papulæ arranged in sixes about paxillæ, lacking from distal three-fifths of arm, as beyond eighth superomarginal.

Superomarginal plates, 30 in number from median interradiial line to extremity of ray, form a slightly arched bevel to margin of ray, but do not encroach so conspicuously upon the abactinal area as in the preceding species. They are uniformly covered with polygonal, flat-topped granules which increase in size toward the lower edge of plates. The thirteenth to twenty-third plates have a rudimentary bare spot near the abactinal end, but this appears to be lacking in a second specimen.

Inferomarginals correspond plate for plate with superomarginals. On disk they encroach more upon the actinal area than do superomarginals upon abactinal. Excepting a regular peripheral series, the granulation is coarse and more irregular than that of superomarginals. The granules tend to become squamiform, and there is a very irregular transverse series of sharp, squamiform spinelets on each plate. These are more numerous in interbrachial arcs, and do not form a straight linear series.

Adambulacrals have an angular furrow margin. Armature as follows: (1) A palmate furrow series of 7 or 8 slightly curved, stout, round-tipped, compressed spinelets. The series is continued along the aboral and adoral margins as 2 or 3 shorter, slenderer spinelets, the inner ones often standing on furrow margin in such a way as to form a portion of the palmate series. (2) On the general surface of plate, 2 (rarely 3, often only 1) lanceolate, slightly flattened sharp spinules similar to those of the actinal intermediate plates. Surrounding these are 6 or 7 blunt, papilliform spinelets,

those on the outer edge of the plate being much slenderer and smaller than those adjacent to the furrow series. The former sometimes form an irregular longitudinal series. The enlarged spinules usually stand in an obliquely longitudinal or even transverse series.

Actinal intermediate plates extend as far as fifth inferomarginal. The series adjacent to adambulacrals is much the largest. Each plate bears near the center 1 (occasionally 2) lanceolate, sharp, flattened, appressed spinule surrounded by well spaced, small spinelets which increase in size from the edge toward center of each plate. The peripheral series is slender, but the more centrally situated spinelets are clavate with flattened, subsquamiform tips. There appear to be rudimentary fascioles between the plates, especially those adjacent to adambulacrals series. The granules become more flat-topped and subsquamiform near the inferomarginals.

The armature of the mouth plates is robust, consisting of a furrow series of stout, curved, round-tipped spinelets, slightly compressed, which are subequal in size, or a trifle smaller at the inner third of the series, and a trifle larger than the corresponding spinelets of the first adambulacrals plate. There is an odd spine at the inner end of the combined pair, in addition to the regular marginals. There is a regular series of about 9 along the margin of the median suture, the inner 2 or 3 spinelets round-tipped and of about the same size as the adjacent furrow spinelets, the outer graduated and bluntly pointed, clavate or papilliform. The furrow series is continued along the margin adjacent to the first adambulacrals, in 5 or 6 smaller spinelets, which increase in thickness toward the outer end of the plate.

Superambulacrals plates present, feebly developed; lacking beyond eighth inferomarginal.

Madreporic body small, nearly hidden by paxillæ, situated very nearly midway between center of disk and inner edge of superomarginal plates.

Color in alcohol, bleached yellowish.

Locality: Type (no. 21159, U. S. National Museum) from station 3474, south coast of Oahu Island, cruise of 1891, 375 fathoms, fine white sand, 2 specimens.

This species differs from the foregoing in having larger rays, more prominent paxillæ, which are very regularly arranged, one or two enlarged spinules on each actinal intermediate plate, and either one or two enlarged spinules on all the adambulacrals plates. It bears closest resemblance to *Pseudarchaster tessellatus* Sladen, from Simons Bay, Cape of Good Hope. From this species it differs in having shorter and wider mouth plates, which appear, in addition, to be relatively smaller. The 2 lineal series of spinelets are not subparallel, but outline a triangle, the base of which is the superficial series adjacent to the median suture. The marginal plates encroach more upon the dorsal and ventral areas, especially in the case of the inferomarginals. The granulation of the latter is coarser than that of superomarginals, instead of being of uniform size, as in *tessellatus*. The furrow series of spinelets is coarser, and there are usually 2 actinal spinules, instead of 1 on each adambulacrals plate. The abactinal paxillæ contain more spinelets, and appear to be slightly larger, and the madreporic body is much smaller or at least less exposed. This form is also related to *Ps. mozaicus* Alcock from the Indian Ocean, but differs in having shorter rays, which are broader at the base, less numerous marginal plates, and actinal interradial plates which extend to the fifth, instead of tenth, inferomarginal. Minor differences are apparent in the armature of the mouth and adambulacrals plates.

A second specimen has the following measurements: R=59 mm.; r=15 mm. R=3.9 r. Thus the rays are a trifle longer than those of *tessellatus*, and judging from the figure in the Challenger report (Asteroidea, pl. xvii, figs. 3 and 4) are also more robust and more gradually and evenly tapered from the interbrachial arc.<sup>a</sup>

#### Family BENTHOPECTINIDÆ Verrill, 1899.

Benthopectinidæ Verrill, Revision of certain genera and species of starfishes with descriptions of new forms. <Trans. Conn. Acad. Sci., vol. x, 1899, p. 217. = Pararchasterinæ Sladen.

#### Subfamily PONTASTERINÆ<sup>b</sup> Verrill, 1894.

Pontasterinæ Verrill, Descriptions of new species of starfishes and ophiurans, etc., <Proc. U. S. Nat. Mus., xvii, 1894, p. 246.

<sup>a</sup> After this report was completed and had left my hands three species, *Ps. pectinifer*, *Ps. pulcher*, and *Ps. verrilli*, were described by Ludwig (Mem. Mus. Comp. Zool., Vol. xxxii, July 17, 1905, p. 106-120). *Ps. jordani* resembles the first two forms, but lacks any structures that might be considered pedicellariæ. From *pulcher*, *jordani* differs, also, in having actual intermediate spines, and a much more extended papular area, reaching to supermarginal plates and interradial line. *Ps. pectinifer* is from Gulf of Panama, and *pulcher* from southwest of Acapulco, and vicinity of Galapagos Islands.

<sup>b</sup> Classified by Verrill under his Plutonasteridæ. The present classification is that advocated by Sladen in "Challenger Asteroidea."

Genus *CHEIRASTER*<sup>a</sup> Studer.

*Cheiraster* Studer, Sitzungsber. naturforsch. Freunde Berlin, 16 Oct., 1883, p. 130; Anhang. d. Abhandl. d. k. preuss. Akad. d. Wiss. Berlin, vom Jahre 1884, p. 49, Taf. IV, figs. 8, a, b, c; Taf. V, figs. 9, a, b, c, d, e. Type, *Cheiraster gazellæ* or possibly *pedicellaris* Studer.

*Pontaster* (partim) Sladen, Narr. Chall. Exp., I, 1885, p. 610.

Key to Hawaiian species of *Cheiraster*.

- a. Pectinate pedicellariæ on actinal surface.....*snyder*  
 aa. No pectinate pedicellariæ.  
 b. Abactinal paxillar area bristling with erect spinules. Rays rather short.....*horridus*  
 bb. No erect, abactinal spinules. Rays long and slender.....*inops*

*Cheiraster snyderi*, new species.

Pl. x, fig. 3; pl. xviii, figs. 1 and 3.

Rays 5. R = 51. mm.; r = 9 mm. R = 5.6r.<sup>b</sup> Breadth of ray at base (between first and second superomarginals) 8.5 mm.

Rays long and slender, tapering gradually to an elongate pointed extremity. Disk rather small. Interbrachial arcs wide and rounded. Lateral wall vertical. The marginal plates form a narrow, slightly raised border to abactinal paxillar area, which is subplane. Pectinate pedicellariæ on actinal surface.

Abactinal paxillar area is not uniform, the paxillæ being of various sizes, spaced, and rather small, decreasing in size toward tip of rays. Larger paxillæ of disk bear 6 to 9 short, papilliform spinelets surrounding a central group of 2 or 3, or sometimes only 1. Scattered among these are smaller paxillæ of all sizes, some with only a single little spinelet, others with 3, 4, 5, or 6, and so on up to the largest. Paxillæ on rays bear 4 to 6 spinelets, usually widely radiating, and on outer half of arm a few along median radial area may have a single, central, delicate, conspicuous spinule standing erect. Those paxillæ on papularium are different from the others, being more ornate, with longer spinelets, which radiate to form rosettes. Midway between center of disk and margin, on each inter-radial line, is a single enlarged paxilla with 20 to 25 spinelets. One of these is situated adcentrally to the madreporic body. Papulæ are large and confined to an oval area at base of rays (papularium), there being about 25 to 30 of them, distributed in 4 irregular longitudinal rows, the 2 medium series longest.

Marginal plates form a slightly raised border to disk and rays, which have vertical sides. Plates of lower series alternate with those of upper, except on outer third of ray, where they very nearly correspond. Superomarginal plates, 33 in number (in cotype) from median interradial line to extremity of ray, are about as high as broad, except in interbrachial arc, where the height is much the greater. They are slightly tumid, form a rounded margin, and the prominent transverse sutures follow an oblique course, trending from within outward and orad. First superomarginal smaller than succeeding ones. Each superomarginal bears 1 short, sharp, cylindrical, tapering spine, at about the center of plate. These diminish in length as they proceed outward and are usually absent from the first superomarginal and reduced in size on second. General surface of plates is covered with small, rather widely spaced papilliform spinelets. There is a small abnormal, odd interradial superomarginal in one interradius.

Inferomarginals form a rounded and conspicuous border to the actinal area, on which their breadth exceeds their length, on inner half of ray, while the reverse is true for outer half. Each plate bears a lateral, cylindrical, tapering, sharp spine, 3.75 mm. long, situated near outer or upper margin and pointing horizontally out from ray. These spines diminish in length as they proceed outward, and are reduced to about half usual size on first 2 inferomarginals. Below each spine, in a rude semi-circle, is a group of 3 or 4 spinules similar to but smaller than the lateral spine. One of these is larger

<sup>a</sup>Ludwig (Mem. Mus. Comp. Zool., vol. xxxii, 1905, p. 1) has united *Cheiraster* Studer and *Pontaster* Sladen (as restricted by Perrier). Pectinate pedicellariæ can not be used as a generic character, for they may be lacking in species normally having them. I have followed Ludwig. *Cheiraster horridus* and *Cheiraster inops* would belong to the restricted genus *Pontaster*, according to those authors who prefer to recognize *Pontaster* as distinct.

<sup>b</sup>In the description the proportions have been taken from the cotype, since tip has been broken from all the arms of the type, which is a considerably larger specimen, r = 11.25 mm.

than the others, and forms a companion spine on all but first 4 or 5 plates. Sometimes a second spinule nearly equals it. General surface of plates is covered with spaced, sharp spinelets or thornlets, which are longest and stoutest along median transverse line, especially in vicinity of spines and spinules. A narrow area at inner end of plates, adjacent to adambulacrals, is usually free from spines, except on about 5 plates beyond the second to fourth. These have 3 or 4 sharp, short spinelets set close together in a comb, and pointed over the suture between inferomarginals and adambulacral plates, sometimes meeting 1 or 2 smaller spinelets on the latter, or arranged in a semicircle without opposing spinelets. These are rudiments of the peculiar pectinate pedicellariæ characteristic of the genus, and which in this species are better developed on the actinal intermediate plates.

Adambulacral plates have an acute angular projection into furrow, the spiniferous rim appearing semicircular. Greatest breadth is greater than length; successive plates rather widely separated. Armature as follows: (1) A furrow series of 8 (occasionally 6 or 7) slightly flattened, blunt spinelets. The 4 or 5 median spinelets form a nearly straight series, are untapered and round-tipped. One or 2 spinelets at either end of series are shorter than the central group of 4, and the lateralmost are shortest. (2) On actinal surface a tapering, stout, erect, pointed spine, a third longer than those of furrow series, stands in the middle of plate, and on an oblique line toward outer adoral corner is a companion spinule, much shorter and slenderer. A second slightly shorter spinule, near the aboral margin of plate, is in a longitudinal series with the last, while a similar third spinelet is sometimes found just aborally from the prominent spine. These 3 spinules are usually all present (but not always) and near base of ray either the first or second may be considerably enlarged. A row of 2 or 3 short, slender spinelets continues the furrow series along adoral margin of plate.

Mouth plates prominent, broad, and the united pair strongly convex, with a wide free margin. Width of united pair exceeds interradial dimension. Each plate bears a marginal series of 7 flattened, tapering, blunt spines and spinules, disposed in a radiating horizontal series. The innermost spine is longest, the second slightly shorter, and the combined 4 stand out horizontally over peristome forming "teeth." The remaining 5 spinelets are either graduated in length, or form an independent fan-shaped series at sides of the margin. On actinal surface a row of 5 or 6 prominent pointed spinules extends along margin of interradial suture, decreasing in length as they proceed outward. About 3 widely spaced spinules are scattered between the above series and the marginals, often forming an intermediate series.

Actinal intermediate plates are few and do not extend beyond fourth adambulacral. There are 8 or 9 pectinate pedicellariæ to each of the 5 interradial areas. These pedicellariæ are situated over a suture between 2 plates, the 4 or 5 spinelets (making up comb) of one plate opposing an equal number of the adjacent plate, the suture running between them. The largest pedicellaria is that on interradial line. The others are smaller. There is considerable variation in the number of these pedicellariæ, the smaller specimen possessing but 2 to 4 to each interradial area, and lacking entirely the largest. Numerous delicate thornlets are scattered over intermediate plates.

Anal aperture subcentral, small, but easily seen.

Madreporic body of medium size, broadly elliptical, situated midway between center of disk and margin. Striations coarse, very irregular.

Color in life unknown; in alcohol ashy white.

Young: The smallest specimen (station 4007) has  $R=11$  mm., and  $r=3$  mm., and a considerably different facies from the adult. The marginal plates are very broad and massive, and encroach upon the abactinal paxillar area. Paxillæ relatively large, especially on disk. Adjacent to the margin in each interradius is a large, round paxilla, evidently the same as that which in the adult is situated about midway between margin and center of disk (basal plate of apical series). There is another smaller plate situated at the base of the ray, in the median line, which probably represents the radial plate. There is only 1 papular pore to each ray, just distad from the radial plate. Madreporic body minute. Spines of marginal plates small. No actinal interradial plates; no pedicellariæ. Adambulacral plates widely separated. Furrow series of spinelets only 3 or 4; actinal adambulacral spinelet 1, with an aborally situated companion. Mouth plates like adult, characteristic. A larger specimen with  $R=28$  mm. has 4 or 5 actinal intermediate plates and a couple of pedicellariæ to each area. There are scattered spinules on abactinal surface of disk, as well as on rays.

Localities: Type (no. 21155, U. S. National Museum) from station 3997, southwest of Kauai Island, 418-429 fathoms, fine gray sand and brown mud; bottom temperature  $41^{\circ}$ . Seven specimens

taken also at the following stations: 3981, southeast of Kauai, 636-414 fathoms, globigerina ooze; 3995, north of Kauai, 427-676 fathoms, fine gray sand and rocks; 3998 southwest of Kanai, 235-228 fathoms, coarse brown coral sand, shells, rocks (very young, probably this species); 4007, vicinity of Kauai, 508-557 fathoms, gray sand, foraminifera (very young). All but types are immature specimens.

*Cheiraster horridus*, new species.

Pl. x, fig. 5, 5a; pl. xvii, fig. 3; pl. xviii, fig. 2.

Rays 5.  $R=35$  mm.;  $r=7$  mm.  $R=5r$ . Breadth of ray at base (between first and second superomarginals) 7 mm.

Rays rather short for genus, tapering very gradually from a narrow base to pointed extremity, which is reflexed. The ray tapers more perceptibly in outer than inner half, giving a stout appearance. Disk small. Interbrachial arcs regular but well rounded. Lateral walls vertical. Marginal plates form a broad, but not raised, border to abactinal area. Abactinal surface of disk and rays subplane; actinal areas subplane; margins of rays well rounded. No pedicellariæ whatsoever.

Abactinal paxillæ are fairly large and distinctly spaced, the plates varying in size and having no definite order. They are irregularly hexagonal, or polygonal, and the convex, spine-bearing surface is only slightly raised above level of sutures. Larger paxillæ of disk bear 15 to 20 small cylindrical spinelets, surrounding in 1 or 2 irregular series a long, slender cylindrical spine (3 to 4 mm.) which stands erect. These spines are numerous on disk, and about 10 scattered, very large paxillæ bear from 2 to 4 accessory spinules about half as long as the spine. On a few of the paxillæ a rosette of enlarged spinelets surrounds base of spine. On rays the spines are numerous, but reduced to one-third or one-fourth the size of those on disk; deciduous and usually not more than 1 to a paxilla. Scattered among the larger paxillæ of disk are numerous small ones, consisting of a central spinelet and 4 to 9 in a rosette surrounding it. Very small paxillæ bear a group of 3 or 4 spinelets. Papulæ are few, very inconspicuous, and are confined to the basal portion of each ray. No specialized papularium is evident.

Marginal plates form a conspicuous border to disk and rays. Plates of the two series are not exactly opposite (except the first pair), but alternate, so that the sutural line between the 2 series is regularly zigzag. Supermarginal plates, about 20 in number from median interradial line to extremity of ray, are about as wide as high, except in interbrachial arc, where height is greatest. They form a conspicuous margin to paxillar area, which on arms is equal to twice the width of 1 series of plates. First plate much smaller than succeeding. Each supermarginal on outer or marginal angle bears a conspicuous slender, tapering, sharp spine, 2 to 3 mm. in length, which stands out at right angles to side of ray. They decrease in size toward tip of ray, and are surrounded each by 2 to 6 smaller spinules of different lengths, the longest being about one-half length of spine. Rest of plate is covered with tiny, spaced spinelets. There are prominent but shallow furrows between the plates.

Inferomarginals are distinctly tumid, and form a rounded and elevated border to the actinal surface. Each plate bears from 5 to 8 slender, tapering, bristling spines and spinules, either disposed in an oblique transverse group, or (on outer half of ray) forming a more compact group on lateral surface of plate. The spines are of different lengths, the longest being equal to supermarginal spine. There are usually 3 nearly as long, while the remainder vary from one-third to one-half the length of longest. Scarcely 2 plates have the armature arranged exactly alike. General surface of plates is covered with small, slender, sharp spinelets, rather widely spaced. A number in the vicinity of spines are enlarged.

Adambulacral plates have a prominent angular projection toward furrow, the furrow margin being rounded or semicircular in outline. Armature as follows: (1) A palmate furrow series of 5 or 6 slender, untapered (or but very slightly tapering), flattened, round-tipped spinelets, the median longest and all slightly radiating. Along adoral margin of plate there are 2 to 4 tiny, slender spinelets, simulating a continuation of the furrow series. (2) On actinal surface of plate are 2 robust, tapering, acute spinules forming an oblique series, the axis of which would extend diagonally across the plate from outer adoral to inner aboral corner. The outer spine is longest (2 mm. on inner half of ray), the inner about equaling longest of furrow spinelets. One or 2 of the delicate adoral thornlets are sometimes found in close proximity to the larger spine.

Mouth plates are broad and convex, the combined width of 2 plates equaling the interradial dimension. Marginal spinelets 7, increasing in length toward inner angle, the innermost being long, tapering, and blunt, the next not quite so long. The 4 spines of companion plates form prominent teeth. The most aborally situated spinelet of furrow series (i. e., the seventh) is about one-third the length of the third spinelet from inner angle, the third spinelet two-thirds length of median teeth. Actinal surface bears 10 or 11 small, scattered spinelets, of which about 3 on each plate are enlarged into spinules.

Actinal interradial areas are very small, with 6 plates, the 2 innermost (opposite mouth plates, much the largest, tumid, and surmounted by 1 or 2 central spinules and 6 or 8 tiny thornlets, like those of inferomarginals. The other plates bear a few thornlets.

Anal aperture nearly central, very small.

Madreporic body small, circular, with coarse striations; situated about its own diameter distant from marginal plates.

Color in life: Abactinal surface vermilion, the tip of arm, and a broad V-shaped transverse band about midway along ray whitish. Actinal surface white. Color in alcohol, ashy white.

Locality: Type (no. 21156, U. S. National Museum) from station 4079, north coast of Maui Island, 143-178 fathoms, gray sand and foraminifera; bottom temperature 60.8°.

This species shows no signs of pectinate pedicellariæ. It is quite different from any described species; the numerous spines on the abactinal surface and bristling armature of both series of marginal plates at once distinguish it. *Pontaster hispidus* Wood-Mason and Alcock, and *Pontaster pilosus* Alcock from the Indian Ocean evidently have pectinate pedicellariæ. The only Pacific forms of "*Pontaster*" (s. s.) are *subtuberculatus* from east of Australia and *planeta* from west of South America, near Straits of Magellan. Both of these forms are widely different from *horridus*. On account of its bristling armature and the absence of a specialized papularium, *horridus* resembles the young of *Acantharchaster* Verrill, which lack pectinate pedicellariæ. In the present form, however, the papulæ seem to be lacking from disk except adjacent to base of rays.

#### **Cheiraster inops**, new species.

Pl. x, fig. 4; pl. xvii, fig. 2.

Rays 5. R=50 mm.; r=7.25 mm. R=6.9r. Breadth of ray at base (between first and second superomarginal plates) 8.5 mm.

Rays long, slender, tapering gradually from a narrow base to an elongated pointed extremity. Disk small. Interbranchial arcs angular, but rounded. Lateral walls vertical. Marginal plates form a rather narrow, slightly raised border to abactinal area, which is subplane. No pedicellariæ.

Abactinal paxillæ smaller than in preceding species; well spaced; abactinal integument rather flexible. The paxillæ, which conspicuously decrease in size toward tip of ray, consist on disk of 9 or 10 very short papilliform spinelets, in a circle, surrounding a central group of from 1 to 4 spinelets. Along median radial area of arm and center of disk numerous scattered paxillæ bear a single, central, short, sharp, tapering spinule. On rays there are usually 5 or 6 very short spinelets surrounding a single central one to each plate. In each interbranchial arc, about midway between center of disk and margin, is 1 paxilla much larger than any other, bearing a coordinated group of about 25 spinelets. Scattered among the larger paxillæ of disk are numerous very small ones. Papulæ are large, confined to an elliptical area at base of rays (papularium), there being 4 longitudinal rows, the 2 median nearly twice as long as the lateral, and their papulæ also larger. Papularium is more prominent in a mutilated specimen than in type, there being 5 to 8 papulæ in the lateral series and 8 or 9 more widely spaced in the median.

Marginal plates of lower series alternate with those of upper, as in foregoing species, the first inferomarginal being opposite first and second superomarginals, the sutural line between the 2 series following a regular angular zigzag course throughout ray. Superomarginal plates, 30 in number from median interradial line to extremity of ray, are higher than broad, except on outer half of ray, where the 2 dimensions are about equal. The plates are tumid and form a rounded, slightly elevated border to paxillar area, the sutures between the plates being set obliquely, as is usually the case in this genus. First superomarginal is conspicuously smaller than the succeeding. Each plate bears a short (1.75 to 2 mm.), tapering, pointed spinule, rather nearer the outer than inner margin of plate. These spinules are borne on the angle where lateral and dorsal superficies meet, and are usually bent upward.

On outer attenuate part of ray they become much reduced in size. First superomarginal either lacks the spinule or bears a very small one. General surface of plates is covered with scattered, small, papilliform spinelets.

Inferomarginals form a rounded and conspicuous border to actinal area, on which their length is greater than their breadth. They are slightly higher than the superior series. Each plate, on lateral face and near upper angle, bears a prominent, cylindrical, tapering, sharp spine, which stands out horizontally from ray. These spines are about 3 mm. long, and decrease in length at tip of ray. Below this are grouped 3 to 5 shorter and more delicate spinules, often in a rude semicircle, the longest being one-half to two-thirds the length of spine. On the inner plates of ray these accessory spinules are usually placed in an irregular transverse series, accompanied by numerous enlarged spinelets. Surface of plates is covered with spaced, usually sharp, papilliform spinelets.

Adambulacral plates have an angular projection into furrow, the spiniferous rim being rounded to subangular. Greatest breadth is greater than length. Armature as follows: (1) A palmate furrow series of 7 slender, tapering, blunt spinelets, the 3 or 4 median subequal, or the median slightly the longest. (2) On actinal surface 1 conical, erect, pointed spine stands in center of plate. On outer part of ray a second smaller spinule is present in an oblique line toward inner aboral corner of plate. This spinule seems to be represented throughout rest of ray by a slender spinelet on the aboral border of plate. First 2 adambulacrals have a second smaller spine toward the furrow angle, but this does not appear to hold for all the rays of the type specimen. Three or 4 small spinelets stand in a row along adoral margin of plate, forming a continuation of furrow series. One or 2 similar spinelets are also occasionally found on outer end of plate near inferomarginals.

Mouth plates prominent, broad, and the united pair strongly convex, with a wide semicircular free margin. Their interradiar length about equals width of united pair. Each plate bears a marginal series of 8 spinelets, the 2 innermost enlarged into flattened, slender, slightly tapering spines, which project horizontally over the mouth and with those of the companion plate form 4 "teeth," the 2 median of which are a trifle the longest. The other marginal spines are about half the length of teeth, and diminish in size as they recede from them. On actinal surface of each plate is a linear series of numerous spinelets, running parallel to median suture, which decrease in size as they proceed outward. Between this series and lateral margin, and much nearer inner than outer end of plate, stands a single prominent spine similar to that which is found on the actinal surface of each adambulacral. Numerous small miliary spinelets are found on outer half of each plate.

Actinal interradiar areas small. Intermediate plates 10 to 12, convex, armed with small, widely spaced, spinelets. Intermediate plates extend only as far as the fourth adambulacral, and usually not beyond third.

Anal aperture nearly central, easily detected.

Madreporic body small, subcircular, situated about midway between center of disk and margin, marked with coarse radiating striations. There is a large paxilla on its adcentral side.

Color in life unknown; in alcohol ashy white, yellowish on arms.

Variations: In a large mutilated specimen which appears to belong to this species the disk is relatively slightly larger, and interbrachial arcs more rounded. The papularium is more prominent also. Each adambulacral plate bears a second smaller spinule in an oblique line toward the outer adoral corner of plate. The inferomarginal plates are slightly broader on actinal surface than in type. It is barely possible this may represent another closely related species, but with the material at hand it is impossible to determine this. The species of *Cheiraster* are as a rule very variable.

Localities: Type (no. 21157, U. S. National Museum) from station 3865, Pailolo Channel, between Molokai and Maui, 256-283 fathoms, fine volcanic sand and rocks; bottom temperature 44.8°. Station 3868, same locality, 294-684 fathoms, fine gray sand and rocks. Cruise of 1891, 3474, south coast of Oahu, 375 fathoms, fine white sand; 8 specimens.

This species can readily be distinguished from the preceding by the longer, slenderer rays, very much less spiny dorsal integument (the spinules being inconspicuous), and less spiny marginal plates. It is apparently more nearly related to *Ch. planeta*, taken by the Challenger Expedition in 245 fathoms off the western coast of South America (near the entrance to the Straits of Magellan, opposite Port Churruca) than to any other known form. From *planeta*, *inops* would be readily distinguished by its relatively smaller disk, more attenuate, longer rays, more numerous papulæ in the papularium, and by the considerably larger abactinal paxillæ. The armature of the inferomarginal and adambulacra; plates also presents points of difference.

## Family ARCHASTERIDÆ Viguièr, 1878 (emend).

Archasteridæ Viguièr, Anatomie Comparée du Squellette des Stellérides. <Arch. Zool. Expér. et Génér., t. vii, 1878, p. 235 (separate). Verrill, Trans. Conn. Acad., vol. x, 1899, p. 201; restricted to genus *Archaster*.

## Genus ARCHASTER Müller &amp; Troschel.

*Archaster* Müller and Troschel, Monatsber. d. k. Akad. d. Wiss., Berlin, 1840, p. 404; System der Asteriden, 1842, p. 65. Emended by Sladen, Challenger Asteroidea, 1889, p. 120. Type *Archaster typicus* Müller and Troschel.

*Archaster typicus* Müller & Troschel.

*Archaster typicus* Müller and Troschel, Monatsber. d. k. Akad. d. Wiss. Berlin, April, 1840, p. 104. J. E. Ives, Proc. Philad. Acad. Sci. 1889, p. 175.

This well known and widely distributed species was not taken by the naturalists of the *Albatross*, although considerable work was done on reefs and dredging was carried on in shallow water. A specimen collected by W. H. Pease is recorded by J. E. Ives (op. cit., p. 175) from the "Sandwich Islands". He says: "The specimen from the Sandwich Islands differs from the others by its narrower arms and greater number of arm plates, having about 40 to each side of an arm, whereas others have only about 35. It differs also in color, being of a very light cream color instead of light or dark umber. This however may be due to fading of the original tint".<sup>a</sup>

An examination of several Samoan specimens reveals the fact that there is some variation in the length and breadth of the rays, while the number of superomarginal plates may be as great as 52.

This species has a certain resemblance to some forms of *Astropecten*, but may be readily distinguished from any member of that group by the absence of superambulacral plates, and by the presence of a very well defined median radial series of paxillæ.

## Family GONIASTERIDÆ Forbes, 1840 (pars).

Goniasteridæ (pars) Forbes, A History of British Starfishes, etc., 1841. Verrill, Trans. Conn. Acad., vol. i, 1867, p. 343.

Perrier, Révision des Stellérides, 1875, p. 185.

Pentagonasteridæ Perrier, Mém. sur les Étoiles de Mer, etc., 1884, p. 231. Sladen, Challenger Asteroidea, 1889, p. 260.

## Key to Hawaiian genera of Goniasteridæ.

- a. Whole test not overlaid with a fairly thick skin or membrane, obscuring the plates.
- b. Abactinal area with tabulate paxilliform plates, either rounded or stellate on the papular area.
  - c. Abactinal plates round, on the radial papular areas connected by internal, slender, very regular, radiating ossicles which are independent of the plates.....MEDIASTER
  - cc. Abactinal plates strongly stellate, 4 to 5 lobed, imbricating by the tips of the processes, which are stout.....NEREIDASTER
- bb. Abactinal area paved with rounded or polygonal plates which may be smooth and bordered by a single series of granules, or their surface may be covered with granules. They may bear isolated spines and short tubercles, or may be covered with short spines and granules invested in pulpy sheaths. Plates not tabulate nor papilliform.
  - c. Form pentagonal to stellate. Superomarginal plates separated on ray by at least one series of abactinal plates; or occasionally 1 or 2 distal superomarginals are in contact medially.
  - d. No prominent spines or tubercles on any of the plates. No enlarged actinal adambulacral spines. Abactinal plates smooth or granuliferous.
  - e. Granules more or less bead-like. No large bivalved pedicellariæ.
  - f. Marginal plates very large and few, the second superomarginal conspicuously larger than either the first or third. Abactinal area granulose.....PENTAGONASTER
  - ff. Marginal plates few to many, evenly graduated in size, neither the second nor any sub-terminal superomarginal conspicuously larger than the preceding plates.....TOSTIA

<sup>a</sup> After this paper was ready for the press I received from Dr. H. A. Pilsbry, of the Philadelphia Academy of Sciences, the above specimen. I have nothing to add to Mr. Ives's observations, except that very few of the superomarginals bear a small upright tubercular spinelet. In one of the Samoan specimens these are conspicuous. The number of superomarginals is not great for the size (R=60 mm., r=10.5 mm.), since a specimen from Samoa, with R=65 mm., has 48 superomarginals. The armature of the adambulacral plates is the same in Hawaiian and Samoan examples.

- ee. Abactinal plates covered with flat granules of considerable size, and irregular, often grotesque shapes. Numerous large bivalved pedicellariæ on both surfaces, but not on marginal plates. Marginal and actinal plates covered with polygonal or irregular granules.....GILBERTASTER
- dd. Marginal plates with rigid tubercular spines, or tubercles.
- e. Distalmost 2 or 3 superomarginal plates in contact medially. Abactinal plates smooth, having a central tubercle on the radial series.....CALLIASTER
- ee. Marginal plates separated throughout the ray. Abactinal, marginal, and actinal plates bearing conical spines surrounded by granules sheathed in a thick, pulpy, investment. EVOPLOSOMA
- cc. Form stellate; many of the distal superomarginal plates in contact medially. Rays slender, at least in outer part; disk well developed.
- d. Abactinal plates smooth, bordered by small, oblong, roundish, or quadrate granules. Actinal plates bearing a few central, tubercular granules, and bordered by bead-like granules. Inferomarginal plates without spines.....ASTROCERANUS
- dd. Abactinal plates granuliferous, bearing erect sharp spines on radial areas. Inferomarginal and actinal intermediate plates bear prominent, mobile, sharp, appressed spines.....CALLIDERMA
- aa. The whole test covered by a membrane or skin obscuring the outlines and surface of the plates.
- b. Papulæ single, medium-sized, not in areas. Abactinal membrane smooth. All granules of test are beneath the membrane. Plates polygonal or roundish, close-fitting. Pedicellariæ elevated, spatulate, pincer-shaped.....ANTHENIASTER
- bb. Papulæ very small; in areas. Integument or skin closely beset with small superficial granules. Plates strongly stellate. Pedicellariæ small, low, slit-like, as in *Pentaceros*...GONIODISCIDES

#### Subfamily MEDIASTERINÆ Verrill, 1899.

Mediasterinæ Verrill, Revision of Certain Genera and Species of Starfishes, with Description of New Forms. <Trans. Conn. Acad., vol. x, Aug. 1899, p. 177.

#### Genus MEDIASTER Stimpson.

*Mediaster* Stimpson, Journ. Bost. Soc. Nat. Hist., vol. vi, 1857, p. 490, pl. 23, figs. 7-11. Type *Mediaster æqualis* Stimpson.  
*Isaster* Verrill, Proc. U. S. Nat. Museum, vol. xvii, 1894, p. 257. Type *Archaster bairdii* Verrill.

The following species of *Mediaster* differs from *M. æqualis*, the type of the genus, in several important respects. The internal connecting ossicles<sup>a</sup> of the abactinal plates are absent from a very definite triangular interradiar area, the roundish or somewhat irregular plates being there in close contact, and the papulæ consequently absent. In *Mediaster æqualis*, however, both the papular pores and the radiating connecting ossicles are present right up to the interradiar septum, there being only a narrow area, where the septum attaches to the abactinal integument, free from papulæ and ossicles. The appearance, when prepared specimens of the two forms are viewed from the internal side, is quite different. In *Mediaster ornatus* the pedicellariæ are more pincer-like, especially on the actinal surface, instead of being low as is the case with *æqualis*. In the Hawaiian species the granules of the abactinal paxillæ are more delicate, ornate, and are not so closely crowded on top of the tabulum as in *æqualis*. In *ornatus* the furrow spines are 6 or 7 in number, delicate and compressed, and disposed in very regular combs. In *æqualis* they are 3 to 5, stout, unequal, subprismatic, not different in thickness from the 2 actinal series.

#### *Mediaster ornatus*, new species.

Pl. xvi, figs. 3, 3a-b; pl. xx, figs. 1, 2.

Rays 5. R=52 mm.; r=21.5 mm.; R=2.42 r. Breadth of rays at base, 21 mm.

Regularly stellate, with a broad disk, usually inflated over radial areas, and with symmetrical, regularly tapering rays, which have a broad base. Rays bluntly pointed. Interbrachial arcs wide and rounded. Sides of body well rounded, actinal surface plane.

Abactinal paxillar area covered with medium-sized, ornate, tabulate paxillæ, arranged in regular series parallel with the median radial. Paxillæ of radial regions and center of disk are more widely

<sup>a</sup> Ludwig (Mem. Mus. Comp. Zool., vol. xxxii, 1905, p. 126) has described *Mediaster elegans* (west of Cocos Island), in which there are no internal connecting ossicles.

spaced and are larger than those of the triangular interradial areas. Paxillæ of median radial series largest, thence decreasing in size toward tip of ray and sides of body. In the radial areas where paxillæ are spaced, the papulæ (1 to a pore) occur in sixes about each plate, emerging between the internal connecting ossicles. Over a triangular interradial area, however, the papulæ are wanting and the paxillæ are closely crowded. Similarly on outer third of arm the plates lose their special tabulate character, the papulæ disappear, and the plates become subhexagonal, closely united, and covered with a coordinate granulation identical with that of adjacent marginal plates. Median radial series extends to terminal plates. As already pointed out, the plates of radial papular area are well spaced, are round, and connected by very regular slender radiating ossicles, there being 6 ossicles radiating from each plate, and each ossicle common to 2 plates. The ossicles terminate abruptly at border of the triangular interradial area, being coextensive with the paxillæ. The tabulum of each plate is roundish, or in the median radial series elongated transversely. It is crowned by a central group of 4 to 6 small, thimble-shaped granules (in radial series) surrounded by about 15 to 17 longer pinched granules on the periphery. Paxillæ at sides of radial areas have only about 3 granules in the central group, and 12 to 15 in the peripheral series; while on the interradial areas they are still smaller. There is considerable variation in the number of granules, there being in some specimens a greater number than above indicated. A few small 2-jawed upright pedicellariæ, each jaw about the size of a granule, are scattered over the paxillæ of disk. They may occur either in the center of tabulum or on the edge. These pedicellariæ are very simple in construction, being but slightly modified granules. Each jaw curves toward its companion, the opposing faces being flat. Anal opening distinct, surrounded by about a dozen granules.

Superomarginal plates, 23 in number from median interradial line to extremity of ray, are broader than high in the interbrachial arc, and about as broad as high on the rays, forming a well-rounded margin to the abactinal area. They are not massive or tumid, nor do they encroach conspicuously upon the paxillar area. On ray they are nearly quadrate, but shorten considerably in the interbrachial arc, and are covered with small, uniform, roundish granules, low thimble-shaped in general form, a peripheral series of slightly longer ones being in evidence. In the center of a few plates of the interbrachial arc is a small pedicellaria, similar to those of the abactinal paxillæ.

Inferomarginal plates correspond in number with superomarginals, but are not opposite to them, being nearly alternate on the rays. Like the superomarginals they form a rounded margin, and are covered with a similar granulation. As a rule there are no pedicellariæ on the inferomarginals.

Adambulacral plates are subquadrate with a nearly straight margin to furrow. Armature as follows: (1) A furrow series of 7 untapered, truncate, subequal spines, strongly compressed and rather delicate, which form a regular comb, their tips conforming to a slightly curved line, and their bases united by a delicate web. (2) On the actinal surface, well spaced from the furrow series, a longitudinal, regular, slightly curved series of 5 to 6 stout, subprismatic (3- or 4-sided) bluntly pointed spinelets about two-thirds the length of those of furrow series and rather more robust, but like them decreasing in length toward tip of ray. Well spaced from the first actinal series, near outer margin of plate, is a longitudinal row of 5 or 6 long, flat-topped or pointed quadrate granules, larger than those of adjacent actinal intermediate plates, between which and the adambulacral granules a bare furrow is present. Near the adoral edge of plate, between the first and second actinal series, a subprismatic spinule or granule may be present which is a constituent of the second series out of line. A tapering spinelet is sometimes similarly present between the furrow and first actinal series.

Mouth plates have a long furrow margin, the companion plates forming a regular angle overhanging mouth and nearly closing the actinostome. Armature as follows: (1) A furrow series of 11 flattened spines, similar to those of the adambulacral plates, which increase in size toward inner angle, the inner 3 being conspicuously larger and broader than the others, and round-tipped, or subtruncate. (2) On the actinal surface a superficial row of spinelets extending along the median suture margin, decreasing in length to mere granules on outer end of plate. The inner members of this series are chisel-shaped. A series of 3 or 4 spinelets runs parallel with the furrow series, and, turning abruptly, is continued along margin adjacent to the first adambulacral in about 4 graduated, prismatic granules. Space between superficial (suture) series of companion plates is conspicuous, elliptical.

Actinal intermediate areas are large, paved with irregularly quadrate or roundish plates which bear subacute or round-tipped prismatic or thimble-shaped granules in a central group and a regular peripheral series, the former being a trifle smaller than the latter. These granules have a pinched

appearance, as if distinctly spaced, and are not so crowded as are those of *Mediaster equalis*. The plates extend along ray to fifteenth inferomarginal, the outer plates being very small and isolated one from another. A few plates bear a low, upright, 2-or 3-jawed pedicellaria, similar to those of the abactinal surface. In some specimens the pedicellariæ consist of little more than 2 or 3 but slightly differentiated granules in a group. On plates adjacent to adambulacrals the pedicellariæ are usually higher, more differentiated, and have rather narrow subspatulate jaws. In one specimen most of the actinal pedicellariæ have 3 jaws, and one has as many as 5. These are higher than the abactinal pedicellariæ, the latter having jaws no larger than the granules.

Madreporic body situated one-third the distance from center; rather small. Striations coarse and characteristic of genus—namely, irregularly radiating but with the furrows interrupted at the central end. Adcentrally to madreporic body is a large paxilla.

Color in alcohol, bleached yellowish or pinkish.

Variations: After the foregoing description was written, and the figures made, 26 additional specimens, most of them adult, were received from the U. S. National Museum. These were taken by the *Albatross* in 1891 off the south coast of Oahu Island. In these specimens the abactinal paxillæ are relatively larger than in the type and fit closer together over the radial papular areas. The abactinal pedicellariæ are larger than those of type, and much more numerous. They are more like the pedicellariæ of *equalis*. They appear almost identical with pedicellariæ of *Mediaster bairdii*, possibly a trifle higher. In some specimens they are very thickly scattered over both radial and interradiæ areas, there being often 2 pedicellariæ on the radial paxillæ. The actinal granules are strongly prismatic.

Considering the specimens collectively, both those from Kauai and Oahu, the chief variations appear to be, in addition to the pedicellariæ, in the number and character of the granules on paxillæ. In some specimens these are more thimble-shaped or roundish, while in others they are distinctly prismatic.

Localities: Type (no. 21160, U. S. National Museum) from station 4022, east coast of Kauai Island, 399–374 fathoms, coral sand, foraminifera, rocks; bottom temperature 41°. Taken also at the following stations, in all 35 specimens.

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
		<i>Fathoms.</i>	
3997.....	Southwest of Kauai Island .....	418-429	Fine gray sand, brown mud.
4019.....	East of Kauai Island .....	550-409	Gray sand, foraminifera.
4021.....	do.....	286-399	Coral sand, foraminifera.
4028.....	Southwest of Kauai Island .....	444-478	Gray sand, globigerina.
4123.....	Southwest coast of Oahu Island .....	352-357	Fine gray sand and mud.
4141.....	East of Kauai .....	437-632	Volcanic sand, foraminifera.

Cruise of 1901:

Station.	Locality.	Depth.	Nature of bottom.
		<i>Fathoms.</i>	
3474.....	South coast of Oahu Island .....	375	Fine white sand.
3475.....	do.....	351	Do.
3476.....	do.....	298	Do.

This species appears to be most nearly related, so far as appearance is concerned, to "*Nymphaster*" *florifer* Alcock, from the Andaman Sea, 130–250 fathoms, which is probably not a *Nymphaster*, but a *Mediaster*.

**Genus NEREIDASTER Verrill.**

*Nereidaster* Verrill, Trans. Conn. Acad., vol. x, 1899, p. 186. Type *Nymphaster symbolicus* Sladen.

The genus *Nereidaster* was erected for the reception of *Nymphaster symbolicus* Sladen, and *Nymphaster bipunctus* Sladen. "In this group the pedicellariæ are high and spatulate, as in *Goniaster* [*Phaneraster* Perrier] and the adambulacrals spines are in very regular parallel rows." (Verrill, l. c.) There is also a single median row of abactinal plates between the superomarginals, which may or

may not attain the tip of the ray. In *bipunctus* most of the superomarginals of the ray are in contact, but in *symbolicus* the abactinal plates extend to the tip of the arm.

I have entertained some doubts as to the propriety of ranking the following species under this genus, but it appears to be closer to *Nereidaster* than to any other known genus. The stellate character of the abactinal plates is not mentioned by Sladen in the descriptions of *symbolicus* and *bipunctus*, as dissection is necessary to determine this point, but the abactinal paxillæ and adambulacral armature, as well as the nature of the pedicellariæ, are essentially the same in the three forms. The condition of the rays, whether long or short, and the degree to which the distal superomarginals are in contact in the median line is apparently not a matter of generic importance.

***Nereidaster bowersi*, new species.**

Pl. xvi, figs. 4, 4a; pl. xvii, fig. 4; pl. xxi, fig. 1.

Rays 5. R=68 mm.; r=32 mm. R=2.15 r. Breadth of ray near base (between fifth and sixth inferomarginals) 23 mm.

Disk very broad, somewhat inflated; rays rather short, stout, tapering to a bluntly pointed extremity. Sides of body rounded, the marginal plates well developed but not massive. Interbrachial arcs very wide and well rounded.

Abactinal paxillar area paved with large, low, tabulate paxillæ, arranged in longitudinal series parallel with the median radial. Paxillæ of latter series are largest, and all decrease in size toward extremity of ray and laterally toward the edge of disk. Paxillæ of the central portion of disk are slightly smaller than at about the middle of each radius. Those of radial areas are hexagonal as to the tabulum, and are considerably elongated transversely in the radial and each adradial series. They become more roundish toward the sides of rays. The triangular interradial area is set off more or less sharply from the radial (the paxillæ being smaller, quadrate or subrhomboid, close-set) and is devoid of papulæ. The papulæ are absent likewise from the outer third of the arm, where paxillæ become suddenly close-set, lose their tabulate character, and are reduced to simple hexagonal plates. Between the distal 8 or 9 superomarginal plates these are reduced to a simple series (the plates often quadrate), which dies out near the tip of ray, the last 2 or 3 superomarginals being medially in contact. In the cotype none of the superomarginals are in contact. Each paxilla springs from a very strongly stellate base, each plate having ordinarily 5 lobes except in the interradial series, where the plates are likely to be rather irregular and with only 3 or 4 lobes. The plates imbricate by the tips of these lobes, between which, in the radial areas, issue the papulæ. The latter are small and single. The tabulum of each paxilla is very low and is surmounted by numerous granules, the number of which varies through wide limits, according to the size of the plate. Over the papular area the granules of peripheral series are slightly pinched, low, square-tipped, more delicate, and often longer than the central granules, which are cylindrical, thimble-shaped, often flat-topped, and on the broader paxillæ of radial area are arranged in 2 or 3 more or less regular transverse series. A large radial paxilla has about 30 to 35 marginal granules and 25 central; while the smaller interradial have 14 or 15 peripheral and 5 or 6 central. In the latter the difference between the central and peripheral granules is hardly noticeable. In the type most of the paxillæ or proximal portion of radial areas and central portion of disk bear in the center a small pedicellaria with 2 (occasionally 3) slender jaws, which are chisel-shaped or spatulate and only slightly longer than the granules.

Superomarginal plates, 25 in number from median interradial line to extremity of ray, are confined almost entirely to side wall in interbrachial arc, but on outer part of ray encroach upon paxillar area, there forming a rounded margin. In interbrachial arc they may be described as forming a very steep bevel. On rays they are much larger, but are not so broad. General surface is covered with numerous low, flat-topped, thimble-shaped granules, there being a very regular peripheral series slightly larger and a trifle more widely spaced. A few pedicellariæ similar to those of the abactinal plates occur at the base of the ray. Distal 2 or 3 plates are in contact medially in type.

Inferomarginals correspond in number with superomarginals, but are not always exactly opposite to them at base of ray. They are much wider than high in interbrachial arc, there conspicuously encroaching upon the actinal interradial area. Outer edges of plates in the middle of interbrachial arc are shorter than the inner ends, like the stones of an arch. Throughout most of the ray the plates are quadrate, but in the interradial arc, and toward tip of ray, they become more and more oblong. Covering of plates is similar to that of the superomarginals. Pedicellariæ rarely present.

Adambulacral plates are subquadrate with a slightly convex margin to furrow. Armature as follows: (1) A furrow series of 7 or 8 slender, parallel, round-tipped or truncate spines, strongly flattened in a plane crosswise to furrow. The central spine is longest, the series being graduated toward either end and forming an elegant and regular comb with a strongly convex edge. The lateral spines are somewhat tapered, and all are united for a short distance above the base by a thin web. (2) On the actinal surface, well spaced from furrow series, a longitudinal row of robust, 4-sided, round-tipped, or truncate spines, either tapered or not. They are stouter, but scarcely so long as the longest furrow spine. Proximal plates have 5 spines, the laterals being very short, scarcely more than granules. Throughout the greater part of the disk there are 3 subequal spines, with a granule at the adoral end of the series and sometimes a smaller spine to the aboral. These become reduced to 2 more tapering and roundish spines on the outer part of the ray. Along the outer margin of plate is a regular series of 4 to 6 irregularly prismatic granules, with 1 or 2 continued along the transverse margins for a short distance. An odd spinelet is sometimes present on proximal plates of the series, on the adoral margin, between the furrow and first actinal series.

Mouth plates of fair size but not prominent, with a truncate outer end, and a long narrow margin. Actinal surface is slightly convex, rising toward the medium suture. Armature: (1) A furrow series of 13 (to 15) round-tipped, strongly compressed spines, which increase in size toward the inner end of plate. The series is not evenly graduated, the inner 3 or 4 spines becoming suddenly longer than the others, which are subequal in length with the furrow spines of the first adambulacral. (2) Parallel with the furrow series is a row of 6 to 8 spines similar to the actinal spines of adambulacrals, and forming a linear series with them. The outer portion of the plate is covered with flat-topped, polygonal granules, a superficial series along the margin of the median suture being usually evident.

Actinal interradial areas are large and paved with irregularly polygonal, quadrate, or roundish plates which decrease in size toward the margin and extend along the ray to sixteenth inferomarginal, or to within 15 mm. of the tip. Beyond the eighth inferomarginal there is but a single series. The plates are covered with numerous low, spaced, thimble-shaped granules, some of which, on the periphery, tend to become quadrate. The granules do not quite attain the edge of the plate, so that a conspicuous shallow furrow surrounds each group of them. On many of the plates of the series adjacent to adambulacrals is a small, 2-jawed pedicellaria similar to but larger than those of the abactinal surface. They have narrow spatulate blades. A few are scattered over the remainder of actinal intermediate area.

Madreporic body of medium size, larger than the surrounding paxillæ, situated nearer center than midway between it and margin of disk. Striations irregular.

Color in alcohol, pinkish gray to pinkish brown.

Variations: The cotype differs from type principally in having the superomarginals separated throughout the ray, the distal 5 to 7 by only a single series of abactinal plates. The paxillæ crowns are slightly more convex, and fewer of them bear entrenched pedicellariæ.

Localities: Type (no. 21161, U. S. National Museum) from station 4134, west coast of Kauai Island, 324-225 fathoms, fine coral and volcanic sand; bottom temperature 43.3°. Taken also at 4132, same locality, 257-312 fathoms, fine gray sand and mud.

Judging solely by external appearances, the *Pentagonaster arcuatus* of Sladen (Challenger Asteroidea, p. 277, pl. LII, figs. 1 and 2, pl. XVIII, figs. 5 and 6) appears to be related to the present form, although the former may be a *Mediaster*. It is not possible to tell exactly until the structure of the abactinal plates is known. *Arcuatus* is not a *Pentagonaster* in the restricted sense.

Named for Hon. George M. Bowers.

#### Subfamily GONIASTERINÆ Verrill, 1899.

Goniasterinæ Verrill, Revision of Certain Genera and Species of Starfishes, with Description of New Forms. <Trans. Conn. Acad., x, 1899, p. 200.

#### Genus PENTAGONASTER Gray.

*Pentagonaster* Gray, Ann. N. H., vol. VI, 1840, p. 280. Type, *P. pulchellus* Gray.

*Astrogonium* (pars) Müller and Troschel, System der Asteriden, 1842, p. 55.

*Stephanaster* Ayres, Proc. Boston Soc. Nat. Hist., vol. IV, 1851, p. 118. Type, *S. elegans* Ayres = *P. pulchellus* Gray.

*Pentagonaster* (Sect. A, a, pars), Perrier, Révision des Stellérides, 1875, p. 12.

*Astrogonium*, Sladen, Challenger Asteroidea, 1889, pp. 263, 285.

*Stephanaster*, Perrier, Exp. Trav. and Talisman, 1894, p. 402. (This is antedated 11 years by *Pentagonaster*.)

*Pentagonaster*, Verrill, Trans. Conn. Acad., vol. X, 1899, pp. 147, 157.

*Pentagonaster* as here used includes the old species, *P. pulchellus* Gray, *P. abnormale* Gray, *P. bourgeti* (Perrier), *P. gunni* Perrier, and *P. dubeni* Gray. It is thus employed exactly as emended by Verrill (1899, p. 157). The following species is nearer to the genus *Tosia*, apparently, than are any of the above-mentioned forms.

***Pentagonaster ammophilus*, new species.**

Pl. XVI, figs. 5, 5a; pl. XXII, figs. 1, 2.

Pentagonal, flat, with nearly straight sides, or in some specimens faintly incurved; not produced into rays.  $R=24$  mm.;  $r=20$  mm.  $R=1.2$  r.

Marginal plates are large, subquadrate, but wider than long, slightly convex, the upper and lower series corresponding except at corners of disk, where there are 2 inferomarginals to 1 superomarginal. There are in the type 6 upper and 8 lower plates on each side of the pentagon. The superomarginal plates form a broad, slightly raised bevel to margin of body, the edge of the pentagon being abruptly rounded. Four plates take up the greater part of each side, the plate nearest the ocular being small. Of these 4 plates the 2 median are smaller than either penultimate plate. The 2 distal plates at each angle are in contact medially. The distalmost plate varies much in size, sometimes being very small, and usually is of widely different size from the opposite companion. Terminal plate is small. General surface of superomarginals is beset with widely scattered, round, inconspicuous granules set in shallow pits, except in the outer (lateral) edge, which is covered with similar, larger, crowded granules. The line of demarcation between the 2 zones is abrupt but irregular, the crowded granules being confined to the vertical side of the disk. On inner margin there are usually 2 or 3 irregular longitudinal series of granules. Surrounding each plate there is, besides all of the above, a very distinct and regular series of bead-like granules.

Inferomarginals are similar to superomarginals in shape, but form a slightly raised border without a bevel. They are similarly beset with granules, there being rather more along the inner and along the transverse margins.

Abactinal surface is plane or very slightly convex. Plates are flat, closely set, regularly hexagonal, in 5 longitudinal rows along the radii, the median radial row easily distinguished and most regular. They are irregularly 5- or 6-sided, on interradii and center of disk, and much larger in latter area, the (apparent) basal and radial plates of the apical system being easily distinguishable. All abactinal plates are covered with close-set, bead-like granules, microscopically pitted or roughened. A peripheral series, more regular and often slightly elongated, especially on plates of radial areas, incloses a central group, which are either coordinated or else arranged in concentric rows. A typical plate from interradii area has 40 granules in the peripheral series, and 75 to 80 in the central group. The larger plates nearly double this number. On 3 or 4 of the regular plates in each radius, and usually on 1 or 2 in an interradius, set in a little pit, is a small 2-jawed, slender, subspatulate pedicellaria. These jaws are ordinarily widely gaping, and rest in special depressions. Base of each jaw is much wider than the distal end.

Adambulacral plates are about twice as wide as long, conspicuously smaller than actinal intermediate plates, and form a very regular series on either side of the narrow furrow. Armature as follows: (1) A furrow series of 4 short, untapered spinelets, strongly compressed, edgewise to furrow. They have round tips and interlock with those of the opposite side of furrow. Either lateral spinelet is somewhat weaker than the 2 central members of the series. (2) On actinal surface 3 (sometimes 4) longitudinal series, each with 2 short, blunt, slightly flattened spinelets, which decrease in size as they recede from furrow. They are not very regularly arranged, and sometimes a fourth row of 2 or 3 spinelets is added, especially along outer half of furrow. There are thus from 6 to 11 spinelets on the actinal surface of each plate—usually about 8.

\* Actinal intermediate plates are large, mostly rhombic, arranged in fairly definite rows parallel to the furrow, the plates decreasing in size as they recede from furrow. They are covered with coarse, cylindrical, round-tipped granules, larger, longer, and less crowded than those of abactinal surface. The special pits of these pedicellariæ are usually surrounded by 4 or 5 more pointed granules, a cleared space being present immediately around the group.

Mouth plates are not raised above the general actinal surface. Companion plates are closely united, their combined width equalling interradii dimension. Free margin of each plate straight, the combined plates forming a rather sharp angle. Furrow series of spinelets is 10, similar to but

slightly shorter than those of adambulacrals, though larger at the inner angle, and tending to become prismatic. The actinal surface is beset with 10 or 11 spinelets, 6 of which are a continuation of the inner, actinal series of adambulacrals and resemble them. A series of 4 or 5 smaller spinelets runs along the suture margin from outer corner of plate, and meets the first series about halfway to the inner end. In the angle thus formed 1 or 2 spinelets may be present in large specimens.

Madreporic body is very small, with a few irregular coarse striations. It is situated at one-fourth the distance from center to margin of disk.

Color in life: Abactinal surface, coral red; actinal surface, whitish. In alcohol, bleached yellowish, both sides.

Variations: The chief variation in this species is probably due to age. At any rate the smaller specimens have more acute angles to the pentagon, the sides of which show a tendency to become incurved very slightly. The number of marginal plates is fairly constantly  $\frac{5}{8}$ . Occasionally 1 or 2 of the marginals is abnormally divided obliquely or longitudinally. Young specimens show more irregularity in the number of marginal plates, since the small distal plate may be absent. One specimen (R=18 mm.) has the following formulas for the 5 sides:  $\frac{5}{7}$ ,  $\frac{6}{8}$ ,  $\frac{6}{8}$ ,  $\frac{7}{8}$ ,  $\frac{6}{8}$ ; another (R=11 mm.):  $\frac{5}{8}$ ,  $\frac{6}{8}$ ,  $\frac{6}{8}$ ,  $\frac{6}{8}$ ,  $\frac{6}{8}$ .

Localities: Type (no. 21162, U. S. National Museum) from station 3919, south coast of Oahu Island, 257-220 fathoms, gray sand; bottom temperature, 45.6°. Taken also at following stations: 4081, north coast of Maui, 202-220 fathoms; 4082, same locality, 220-238 fathoms; 4083, same locality, 238-253 fathoms; all on gray sand.

This species may be readily distinguished by its strictly pentagonal form, by the very massive marginal plates, which are few in number (only 3 to a "ray" in the upper series) and especially by the fact that the distalmost but one of the superomarginals is conspicuously larger than the rest. Also the actinal and abactinal plates are granular and bear pedicellariæ. *Pentagonaster ammophilus* is very distinct from any other species of the genus, none of which are so regularly pentagonal. In the relative sizes of its marginal plates it resembles most nearly *P. bourgeti* Perrier, although the latter has 4 superomarginals to a ray instead of 3, and 2 small plates between the terminal and enlarged superomarginal instead of 1, as in *ammophilus*.

#### Genus TOSIA Gray.

*Tosia* Gray, Ann. N. H., vol. vi, 1840, p. 281. Type *T. australis* Gray.

*Astragonium* (pars) Müller and Troschel, System der Asteriden, 1842, p. 55.

*Tosia*, Gray, Synopsis, 1866, p. 11, pls. iii and xvi.

*Pentagonaster* (Sec. A, b, pars) Perrier, Révision des Stellérides, 1875, pp. 200, 204.

*Pentagonaster* (pars), Sladen, Challenger Asteroidea, 1889, p. 264. Perrier, Exped. Trav. and Talisman, 1894, pp. 389, 390.

*Tosia*, Verrill, Trans. Conn. Acad., vol. x, 1899, pp. 148, 158.

#### Key to Hawaiian species of *Tosia*.

- a. Abactinal plates naked, bordered by a series of small spaced granules. Pedicellariæ conspicuous. *ceramoidea*  
 aa. Substellate; abactinal plates small and numerous, covered with granules.....*micropeltata*

#### Subgenus PLINTHASTER Verrill.

Section B. *Plinthaster*, Verrill, Trans. Conn. Acad., vol. x, 1899, p. 161.

#### *Tosia* (*Plinthaster*) *ceramoidea*, new species.

Pl. xvi, figs. 6, 6a; pl. xxii, figs. 3, 4.

Form pentagonal, flat, slightly prolonged at the angles, where 2 of the marginal plates are in contact medially. Sides are fairly straight in fully grown specimen, but in young are decidedly incurved. R=36 mm.; r=25 mm. R=1.44 r.

Marginal plates are large, but relatively much smaller than in *P. ammophilus*, and do not encroach so conspicuously upon dorsal and ventral areas. Sides of body perpendicular or superomarginal plates slightly overhanging inferomarginals. The dorsal and ventral series of marginal plates correspond in position—i. e., do not tend to alternate, the suture between the 2 series being nearly straight. There are, in type specimen, 14 superomarginals and 16 inferomarginals. Superomarginal plates are slightly tumid, about as broad as high, forming a rounded, slightly overhanging edge to the disk. The cord

of the height of each plate exceeds the length. Two distal superomarginals are in contact medially at each disk angle. The general surface is smooth, though microscopically roughened with regular pits and bosses, but on it are about 30 scattered, low, round granules set in shallow depressions. These are usually absent from a narrow zone around the margin. A regular series of flat, roundish, bead-like granules surrounds each plate, and on the dorsal surface there are 1 or 2 small, 2-valved spatulate pedicellariæ on a few of the plates nearest interradial line. Terminal plate is small, armed with a short, blunt spinelet.

Inferomarginal plates encroach upon actinal area more than superomarginals upon abactinal; slightly tumid; twice as broad as high, forming a slightly raised, rounded border to the actinal surface. Width slightly exceeds the length. The surface is beset with scattered granules, similar to those of superomarginals but more numerous, and each plate is surrounded by a regular series of bead-like granules. A narrow zone along upper or lateral face of plate is usually free from scattered granules, and 1 or 2 spatulate pedicellariæ usually take their place. Distal inferomarginal is diminutive.

Abactinal surface is very slightly convex to plane, often depressed in interradial areas. On radial areas plates are regularly circular, or faintly hexagonal, fairly large, close-set, the spaces between them being occupied by papule. The latter are absent from interradial areas, where the plates are less regular, usually hexagonal, sometimes quadrate or pentagonal in outline, and of less uniform size. All plates decrease in size toward the margin, and toward center of disk. The general surface of a plate is nearly flat, destitute of deciduous granules, but roughened by numerous minute bosses or low protuberances. Surrounding each plate, and occupying space between adjacent plates, is a peripheral series of flattened bead-like granules, with rounded or flattened tips. Numerous pedicellariæ, similar to those of marginal plates, are present on abactinal surface.

Adambulacral plates are about as wide as long, with straight furrow margin, but often with an angular outer margin. They are conspicuously smaller than the adjacent series of actinal intermediate plates. Armature as follows: (1) A furrow series of 7 (sometimes 6 in smaller specimens) stout, blunt spinelets, compressed, placed edgewise to furrow. They stand subparallel, and usually perpendicularly to actinal surface. (2) Following these, on the actinal surface, a longitudinal series of 3 short, blunt spinelets about two-thirds the length of furrow spinelets. Then comes another longitudinal irregular row of 3 or 4 blunt, conical granules, and on outer edge of the plate a series of slightly smaller granules 4 to 7 in number. The ambulacral furrow is very narrow, the furrow spines of the 2 sides interlocking.

Actinal interradial areas paved with rather large plates, mostly irregularly 4-, 5-, and 6-sided. They are arranged in fairly definite series parallel to adambulacrals, and the plates diminish in size toward the margin, the largest plate being in the angle adjacent to mouth plates. All are covered with numerous, coarse, but not crowded, rounded or subconical granules, and a more or less definite peripheral series is distinguishable on each plate. A few plates toward the mouth angle bear 1 or 2 two-jawed spatulate pedicellariæ, similar to those on the marginal and abactinal plates.

Mouth plates are plane, each with a straight free margin. Marginal spinelets, 7 or 8, are blunt, stout, and about as long as furrow spinelets of adambulacrals, of which series they are a simple, straight continuation. Most of the spinelets are 3- or 4-sided, and increase slightly in size as they approach the inner angle. On the actinal surface there is a row of 3 to 5 smaller, irregular, often pointed, thick spinelets parallel to furrow series, and a row of several low, rounded, or subconical granules along margin of medium suture and 3 or 4 along that edge of plate adjacent to first adambulacral plate. The outer end of the united pair of mouth plates is broadly truncate. Granules are conspicuously larger than those of the actinal intermediate plates.

Madreporic body relatively larger than that of *P. ammophilus*, about the size of surrounding plates; subcircular; striations of medium coarseness, irregularly radiating. The body is surrounded by small flat granules, like rest of abactinal plates.

Color in life, buff pink; in alcohol bleached yellowish to whitish.

Variations: A small specimen ( $R=21$  mm.;  $r=12$  mm.) has the sides of the disk decidedly arcuate, the relation of the major to minor radius being as 1.75 to 1, instead of 1.44 to 1, as in the type. Superomarginals of young specimen encroach more upon abactinal area than do those of the adult.

Localities: Type (no. 21163, U. S. National Museum) from station 3883, Pailolo Channel, between Maui and Molokai Islands, 277-284 fathoms, globigerina ooze; bottom temperature 45.2°. Taken also at the following stations: 3865, same locality, 256-283 fathoms, fine volcanic sand, rocks; 4082, north

of Maui, 220-238 fathoms, gray sand; 4096, northeast approach to Pailolo Channel, 272-286 fathoms, fine gray sand.

This *Tosia* appears to belong to Verrill's "Section B. *Plinthaster*" (op. cit., p. 161), which probably deserves recognition as a subgenus. The subgenus is thus characterized: "Pedicellariæ with narrow blades are present, of small size, about equal to the granules or but little larger. Adambulacral plates are wider, about as large as the actinal plates, and bear many crowded spinules; usually 4 to 6 in the furrow series. Marginal and abactinal plates usually naked in the middle and often areolated. Three to five of the dorsal marginal plates are usually in contact medially" (op. cit., p. 161). The only modifications to this diagnosis which our species would necessitate is that the pedicellariæ are decidedly larger than the granules, and adambulacral plates are smaller than adjacent intermediate plates. The present species would line up with *T. compta* Verrill and *T. nitida* Verrill from the West Indies, in which pedicellariæ occur in both series of the marginal, and on the abactinal plates, and are set in special bilobed pits. Upper marginal and abactinal plates are granulated around the edges. In our species there are scattered granules on the upper marginal series of plates in addition to those around the edges, while there are also pedicellariæ on actinal intermediate plates. The special bilobed pits are shallow.

This species is the first of the subgenus to be recognized from the Pacific, the others being Atlantic.

A fair figure of the general form and appearance of *Tosia (Plinthaster) perrieri* (Sladen) is to be found in Perrier, *Expéditions Scientifiques du Travailleur et du Talisman*, pt. 1, Echinodermes (pl. 25, figs. 1a, 1b). Probably Professor Verrill considers this the type of the subgenus.

#### Subgenus CERAMASTER Verrill.

Section C. *Ceramaster* Verrill, *Trans. Conn. Acad.*, vol. x, 1899, p. 161. Type *Tosia granularis* (Retzius), i. e., *Asterias granularis* Retz.

#### *Tosia micropelta*, new species.

Pl. XXI, fig. 2; pl. XXVI, figs. 4, 4a.

Stellate; rays 5.  $R=56$  mm.;  $r=29$  mm.;  $R=1.93r$ . Breadth of ray between first and second superomarginals, 28 mm.

General form flat, with a large disk, produced into 5 short rays, which taper evenly from a broad base to a bluntly-pointed extremity. Interbrachial arcs very wide and rounded. Abactinal surface slightly inflated. Actinal surface subplane. Marginal plates conspicuous but not tumid, forming an even border to body. Rays and disk perfectly rigid. Pedicellariæ present only on actinal surface.

The 2 series of marginal plates are not precisely opposite, plate to plate, on ray, but very nearly so. The superomarginals, 13 in number from median interradiial line to extremity of ray, are much broader than high on disk and inner two-thirds of ray, but on outer third of ray the height and width become more nearly equal. The abactinal surface of the plates slopes gently off in a sort of bevel and meets the low lateral face, which is perpendicular. In the interbrachial arc the plates are only slightly wider than long, the length very gradually diminishing as they approach extremity of ray. Abactinal surface of each superomarginal has a large roundish bare space, the lateral face of plate being covered with low roundish granules, which decrease in size toward the margin and likewise surround the abactinal naked area in 1 or 2 peripheral series. On outer half of ray the bare space encroaches more and more upon lateral face, until the last 6 plates have only a marginal series of bead-like granules. The granules are low and sunk into a very thin membrane, and those of the peripheral series are slightly smaller than the others. A small, spatulate, two-jawed pedicellaria is present between 2 of the proximal plates.

Inferomarginals equal the superomarginals in number, but are slightly larger. They are much broader than high, encroaching more upon actinal area than do the dorsal marginals upon the abactinal. Plates are covered with granules similar to those of superomarginals, there being a small round naked area in the center of the actinal face of each, smaller in size than the corresponding areas on dorsal series. The outer 3 or 4 plates have only a single series of peripheral granules, the general surface being naked. Terminal plate large, short, and armed with a heavy thimble-shaped tubercle.

Abactinal area paved with small, roundish plates compactly placed, small papulæ issuing between them, except on a limited area in interradiial region, where they are absent. Papulæ are single, and 4

or 5 are grouped about each plate, any papula being common to 3 or 4 plates. Secondary plates, of somewhat smaller but not uniform size, are scattered without order among the other plates, being most numerous on interradian areas, and on disk; not so common on rays. Each of the larger (primary) plates bears 1 to 4 (usually 2 or 3) subglobose low granules in the center, surrounded by a peripheral series of 7 to 10 similar, but usually somewhat larger ones. The smaller plates bear usually 3 to 6 granules, according to their size. The granules appear as if immersed in a very thin membrane, which, however, does not extend from plate to plate. Over a narrow interradian area (the radial papular areas being wide) the plates are often quite irregular. They are usually roundish to subquadrate. Many of them bear on the margin a small, upright, two-jawed spoon-shaped pedicellaria about the size of the granules. The jaws are often curved like bull-dog forceps. They are less common on the basal portion of the radial areas.

Adambulacral plates have a straight furrow margin, and are nearly as wide as long, the outer margin being often irregularly angular. Armature as follows: (1) A furrow series of 6 (5 on first few plates) short, stout, blunt, nearly untapered, cylindrical to faintly 4-sided, and not very uniform spinelets. The adoral spinelet is slightly the heaviest. The 6 are subequal in length or slightly graduated toward the aboral end of series. Occasionally the central 4 are a trifle weaker than the laterals, which may also be rarely a trifle shorter. (2) On the actinal surface 2 longitudinal series of granules immersed in a delicate membrane, which makes them appear shorter, in the undried state, than they actually are. The first series is well spaced from furrow spinelets, and consists of 3 or 4 subconical granules in a fairly straight series. On outer third of ray one of these enlarges into an upright, thick, cylindrical, tapering, sharp spinule, increasing in size toward extremity of ray. The granules of the outermost series are a trifle smaller, 5 or 6 in number, and follow the border of plates. When the latter is angular, an intermediate granule is often present between the 2 series. On the outer, spiniferous plates there are usually 3 rows of granules, irregular.

Mouth plates are large, with truncate outer ends, and a long furrow margin. The combined pair are prominent actinally, with a broad median suture. Furrow margin very nearly equals length of median suture. Armature as follows: (1) 10 short, stout, spinelets, 3- or 4-sided, blunt, shorter than adambulacral furrow spinelets, and not uniform as to form and length. Innermost spinelet is abruptly enlarged into a tooth; sometimes flattened, or slightly tapering, stout. (2) On actinal surface are numerous granules similar to those of adambulacral plates, a rather definite series being present along the margin of median suture, the innermost member of which is abruptly enlarged into a stout tapering prismatic spinelet. A row parallel with the furrow series, well spaced from it, is continued along the margin adjacent to first adambulacral, to meet the superficial series at its outer end. On the triangular area thus enclosed are 2 or 3 granules. All are invested by a very thin membrane which is hardly noticeable.

Actinal interradian areas are large, paved with large, irregular, quadrate to hexagonal plates, which decrease in size toward the margin. These plates extend two-thirds the length of the ray or to seventh inferomarginal. The plates adjacent to adambulacrals are largest and most regular. All are covered with low subglobose granules, a peripheral series being apparent by their more regular arrangement and slightly smaller size.

Madreporic body is large, subcircular, and is situated a trifle more than one-third the distance from the center to margin. Furrows or striations are narrow, irregular, inconspicuous, and interrupted.

Anal opening is subcentral, prominent.

Ambulacral furrow is very narrow, the tube feet with large sucking disks.

Color in life, pinkish buff; in alcohol, a bleached yellowish white.

Locality: Station 4151, vicinity of Bird Island, 800 to 313 fathoms, fine coral sand, foraminifera, stones; bottom temperature, 37.8°. Estimated that the trawl took bottom at about 800 fathoms depth, and was dragged up steep slope. Type no. 21164, U. S. National Museum.

This species appears to belong to that section of *Tosia*, called *Ceramaster* by Professor Verrill, characterized by having "all the plates above and below usually granulated nearly or quite all over, unless rubbed; in some species the marginal plates may often have a small, naked, central area. Adambulacral plates with 4 to 6 furrow spines." (Op. cit., p. 161.) This subgenus is mainly Atlantic in distribution.

Genus *ASTROCERAMUS*, new.Type *Astroceramus callimorphus*, new species.

Resembles *Iconaster* Sladen (type *Astrogonium longimanum* Möbius) in general form, but differs in the following respects: Marginal plates centrally beset with rather coarse deciduous granules; third superomarginal (at base of ray) conspicuously larger than rest of series; abactinal plates bordered by small, simple granules, not by "very peculiar valve-like plates" (Sladen); actinal intermediate plates bear numerous tubercular granules; adambulacral plates of fair size, the furrow armature consisting of 5 rather stout, untapered, somewhat compressed, roundly truncate spines which are about as long as the furrow margin of the plate. The 2 median spines are slightly the larger, or 4 are subequal and nearly parallel. The adoral spine is nearly always conspicuously shorter than the others. On actinal surface of plate is a series of 2 stout, blunt, erect, cylindrical, or swollen spines more robust and slightly shorter than the furrow series, while on the outer portion of the plate are 7 to 11, stout, irregular or thimble-shaped granules, often angular in drying, simulating 2 longitudinal series, those nearest the actinal spines largest. Rarely a plate bears a large, two-jawed, spatulate, serrate pedicellaria. Similar pedicellariæ occur on the actinal intermediate areas.

It will be seen that this adambulacral armature is considerably different from that of *Iconaster*, whose adambulacral plates are small, the furrow spinelets being small and squamous, and the actinal of about the same size and disposed in several series (*I. longimanus*, Dujardin and Hupé, Hist. Nat. des Zooph. Echin., 1862, p. 377, under *Astrogonium souleyetii*). In *Iconaster pentaphyllus* (Alcock) also the adambulacral plates are small, with a semicircular furrow series of 10 or 11 small foliaceous spinelets in the basal half of ray and 8 to 6 in apical half, of which those at ends of series are thickened; while actinally there are 3 irregular longitudinal rows of depressed granules.

The character of the superomarginal plates is, I believe, one of importance. The granules surrounding the abactinal plates of *Astroceramus* can not be construed into "very peculiar valvular plates," since they are not plates at all. In *Astroceramus* the marginal and actinal plates are granular, not smooth as in *Iconaster*.

*Astroceramus callimorphus*, new species.

Pl. XXIII, figs. 1-3; pl. XXVII, fig. 3.

Rays 5. R=82 mm.; r=24.5 mm. R=3.35 r. Breadth of ray between second and third superomarginal 15.5-18 mm.; between third and fourth 12.5-15 mm.

Rays long and tapering, rigid, fairly slender after the basal expansion is passed; extremities pointed. Interbrachial arcs widely rounded. Lateral walls thick and massive, nearly vertical, but distinctly concave along the sutural line between upper and lower series of plates. Abactinal area plane; actinal subplane.

Abactinal area covered with large, flat, naked plates, irregularly polygonal. Those of radial and either adradial series are subcircular or hexagonal in outline, and are more regular than the others. Those plates of the interradial triangles are usually irregularly 5- to 6-sided. All decrease in size as they recede from the center, the largest plates being those of the primary apical system. All these plates are confined to the disk, except 4 or 5 small quadrate plates isolated between superomarginals near base of ray. These small plates are separated from one another and alternate with the superomarginals. Abactinal plates are surrounded by a series of small, oblong or quadrate granules, flat-topped and set flush with the general surface. The outer free edge of the granules is sometimes rounded. The general surface of plates is plane, or very slightly convex, free from granules, but roughened by minute bosses. In spaces between the plates small papulæ may be seen, although they are absent from a small triangular interradial area (the outer side of which is bounded by the interradial pair of superomarginal plates).

Marginal plates are massive and tumid, the upper and lower series not exactly corresponding on the ray. The superomarginals, 19 in number from median interradial line to extremity of arm, are much broader than high, and form a wide margin to body. Their outer free angle is abruptly rounded, and the length of each plate is about two-thirds to three-fourths the greatest width when the animal is viewed from above, but on the outer part of ray the 2 dimensions are nearly equal. The plates decrease in size both ways from third superomarginal. Tumid portion of both dorsal and lateral surfaces is covered with scattered, low, round granules, which leave a wide, perfectly free area

about the periphery of the plate. On outer part of ray these granules are fewer in number and are confined to the rounded edge of the ray. Margin of each plate is bordered by a series of small bead-like granules, smaller than those of the dorsal plates.

Inferomarginal plates correspond in number to superomarginals, and have about the same general dimensions, except that first and second inferomarginals are the largest of series. Ornamentation is the same as that of superior series, but the peripheral granules are larger. At inner edge of 3 or 4 plates near base of ray (about fourth to seventh inclusive) is a 2-jawed spatulate pedicellaria, like those of the actinal intermediate plates (q. v.).

Adambulacral plates are wider than long, with a faintly convex margin to furrow. Armature as follows: (1) A furrow series of 5 rather stout, untapered, somewhat compressed, roundly truncate spines which are about as long as the furrow margin of plate. These spines are not so obviously compressed on outer portion of ray and are there somewhat tapering. The 2 median spines are slightly the longer, or 4 are subequal and nearly parallel. The adoral spine is nearly always conspicuously shorter than the others, rarely tapering, and set at an angle with the rest of the series. (2) On the actinal surface, spaced a little from the furrow series, a longitudinal row of 2 short, blunt, erect, cylindrical or swollen spines, more robust, and slightly shorter than the furrow spines. This series decreases to a single spine, on the outer third of ray. Occasionally 3 spines are present in the series. On the outer portion of the plate are 7 to 11 stout, irregular or thimble-shaped granules, often angular in drying, irregularly placed or simulating 2 longitudinal series. Rarely a plate bears a large 2-jawed spatulate pedicellaria like those of actinal intermediate plates. One or 2 small, robust spinelets usually stand on the adoral margin near the furrow, forming a sort of continuation of the furrow series. The short adoral furrow spine appears to be one of these moved to the furrow margin. On the aboral edge there is sometimes a similar spine near the furrow.

Mouth plates are rather large but not especially prominent. Each plate forms a wide isosceles triangle, the base toward median suture. Free margin extensive. Actinostome very small. Armature as follows: (1) A furrow series of 7 stout, flat, truncate, or roundly tipped spines, increasing in length toward the inner angle. Some of the spines show a tendency to become prismatic. The plane of flattening is transverse to furrow. The inner spines are conspicuously enlarged and vary somewhat in shape. They are compressed to a thin blade with a truncate tip, which is broader than the base, so that the spine resembles a long hatchet-blade. At one mouth angle, however, the 2 teeth are not conspicuously widened. (2) On actinal surface, a superficial row of tubercles and spines present along the margin of median suture. The inner 2 are heavy, subprismatic, blunt. Rest of series (4 to 5) are blunt, irregular, subprismatic tubercles, or large granules, similar to those of adambulacrals. One inner spine and 2 or 3 tubercles form a similar series along the margin adjacent to first adambulacral. All are rather widely spaced.

Actinal interradiar areas are large, and extend to fourth inferomarginal (in 1 ray to sixth). Small, isolated, intermediate plates extend on 1 ray as far as seventh inferomarginal. Intermediate plates are large, irregularly 4- to 5-sided (rarely hexagonal). The series adjacent to adambulacral is largest; all decrease in size toward margin. Each plate is surrounded by a series of unequal, bead-like granules, and on the general surface there are 1 to 5 larger, thimble-shaped granules, scattered irregularly and widely spaced. Many of the plates adjacent to the adambulacrals, as well as 1 to 3 others in the interbrachial region, bear a single, large, 2-jawed, spatulate, tongs-like pedicellaria. Each jaw has a distal expanded portion with a curved, serrate edge, and a narrower pedicel which again expands at the base to be inserted into a special slit. The special depressions for the jaws when opened are shallow. Five pedicellariæ have 3 jaws each.

Madreporic body is inconspicuous, irregularly hexagonal (shield-shaped), surrounded by 3 large plates. It is situated one-third distance from center of disk to extreme margin. Striations are of medium size, irregularly radiating.

Anus subcentral, small, surrounded by enlarged granules.

Tube feet with large sucking disks. Ambulacral furrow narrow and arched over by the armature of adambulacral plates.

Color in life not taken; in alcohol, bleached yellowish, with a pinkish cast on superomarginals.

Locality: Station 3857, Pailolo Channel, between Molokai and Maui islands, 127-128 fathoms, fine sand, yellow mud; bottom temperature 62.5°. One specimen, type no. 21165, U. S. National Museum.

Genus *CALLIDERMA* Gray.

*Calliderma* Gray, Proc. Zool. Soc., 1847, p. 76. Type, *C. emma* Gray, P. Z. S., 1847, p. 77; Ann. N. H., vol. xx, 1847, p. 198.

*Calliderma spectabilis*, new species.

Pl. xxiv, figs. 1, 2; pl. xxv, figs. 1-3; pl. xxvi, fig. 3.

Size large; form pentagonal, the angles prolonged into rays, the outer attenuate portion of which is formed by marginal plates only. General form depressed, flattened, abactinal surface subplane to slightly convex. Interbrachial arcs are very wide, the interradial portion of the margin of disk being straight and passing gradually into the rays, which have thus a broad base and taper rapidly into the elongated slender outer portion, the distal 20-26 superomarginal plates of adjacent sides being in contact medially. Disk is very large in proportion to rays.  $R=202$  mm.;  $r=85$  mm.  $R=2.37r$ .

Marginal plates are well developed, forming a stout border to disk, but relatively not so large as in *C. emma*. Plates of upper and lower series do not exactly correspond in number, nor are they exactly opposite, except sometimes for a short distance on either side of the interradial line. Throughout most of the ray they are usually alternate, the suture between them having a zigzag course. Edge of disk is square-cut on both surfaces, the lateral surface of the plates sloping inward toward the suture between the 2 series, so that the lateral face of disk and rays is concave or like a shallow V-shaped trough.

Superomarginal plates are broader than high and about as high as long. In interbrachial arc the outer margin of each plate is often slightly shorter than the inner, but the plates are irregular in this respect. Surface of plates subplane to slightly convex. There are 90 to 94 to each side of the body (more numerous in the largest specimen; 77 in a medium small specimen). General surface is covered with numerous, crowded, low, round, flat-topped granules, a marginal series being usually distinguishable. Granules of the latter become subconical along the margin adjacent to inferomarginals, and those of the lateral face of plate are more rounded than on dorsal surface. On the angular margin, where lateral and dorsal superficies meet, each plate bears 2 to 4 stout, short, tapering, very sharp spinules in a longitudinal series, and they extend along the ray to within 4 or 5 plates of where the 2 series of superomarginals meet medially. Throughout rest of ray they are absent.

Inferomarginals are slightly larger than the superomarginals, and also a little higher, their width on the actinal surface being greater than that of the superomarginals on the abactinal. They form a raised border to the ventral surface. The free margin is rounded on the outer part of ray. General surface is covered with flattened granules, similar to those of the dorsal marginals, but on the actinal surface these are rather more squamiform and subacute. The actinal surface is beset with prominent, tapering, occasionally slightly flattened, sharp, mobile spines, about 5 mm. in length, there being 12 to 20 to each plate. They are smaller and fewer in number on the outer part of the ray.

Abactinal surface is capable of some expansion. Plates are flat, hexagonal, and regular on the radial areas, a papular pore being situated at each angle of the hexagon. The papular area is widest in the basal radial area, constricting on the ray and toward center of disk, where there is a narrow circular papular area (bounded externally by the madreporic body) surrounding the anus. The large triangular interradial area is devoid of papulae, and is paved with mostly 4-sided plates, which, like those of the radii, decrease in size as they recede from the center. They are covered with crowded, round, flat-topped or only slightly convex granules, larger than those of superomarginals. These granules increase in size toward the center of disk, and the centrally situated granules of each plate are slightly larger and usually more convex than are those at the sides. The plates of the radial papular areas are armed with larger, globular granules, one much enlarged, and often subconical, with 3 or 4 similar granules nearly as large grouped around it. Along the proximal portion of each papular area the plates of the 3 to 6 median longitudinal series bear each an erect, central, conical spine, as long or longer than the inferomarginal spines (5 mm.). In the type this spiniferous area is 50 mm. long by 15 to 20 wide. There are, besides, 5 stout spines around the anal opening. These abactinal spines are very characteristic and are more conspicuous in the medium-sized specimens than in the "giants," such as the type. The radial and either adradial row of spines are the longest and subequal; while a varying number of lateral shorter series is added at either side. Granules are often arranged in circles about the base of a spine, and the enlarged central granule of the other plates of radii is graduated in size in such a manner as to become smaller as it recedes from the spines. On the ray 3 to 6 granules larger than the others replace this central granule.

Adambulacral plates have a straight margin to furrow. The width of each plate is about two-thirds the length. The armed portion of actinal surface has the appearance of being more or less elevated above the level of the furrow margin. Armature as follows: (1) A furrow comb of 12 to 15 straight, untapered, slightly flattened, roundly tipped spinules, standing parallel. The proximal plates bear usually 12 spinules; those more distantly situated 14 or 15, while the plates at the tip of the ray only about 9. The lateralmost spinelets are shortest. A very characteristic feature of these spinules is that their tips do not conform to a straight or a regularly curved line, but rather to a compound curve. That is, the adoral half of the series is longer than the aboral, the exact relations showing better by figure than description. (2) The actinal surface of proximal plates bears about 6 erect, stout, tapering, sharp, movable spines disposed in 2 regular, or irregular, longitudinal series, or else without very definite arrangement. They average from 5 to 7 mm. in length. One of them is usually longer than all the rest, while frequently 1 or 2 others are not more than half as long as the longest. These actinal spines are reduced to 3 or 4 at about the middle of the radius, and to 2 on the outer attenuate portion of the ray. They are then arranged in an oblique transverse series, on the aboral half of the plate, the axis of the series running from the inner aboral corner to the middle of the outer edge. Proximal adambulacrals bear fewer actinal spines in medium sized and small individuals. Numerous large, irregularly subprismatic or squamiform granules are grouped about the border of each plate, except, of course, on the furrow margin.

Actinal interradial areas are very large, the intermediate plates extending along ray to nineteenth inferomarginal (from median interradial line) or to within 2 plates of the point where superomarginals of adjacent sides join medially. The plates are large, distinct, flat or slightly convex, irregularly 4 or 5 sided (occasionally hexagonal), those adjacent to the adambulacrals largest and most regular. All plates decrease in size as they approach the margin. They are covered with coarse, roundish, or sub-squamiform granules, a peripheral series of smaller, closer ones being usually distinguishable. Each plate bears a central, sharp tapering prominent spine about 5 mm. in length. The plates adjacent to adambulacrals usually bear 2 or 3 in a transverse series, these being longer than the spines over remainder of interradial area. Likewise the proximal plates of the next 2 longitudinal series bear each 2 spines.

Mouth plates are small and narrow, the width of the united pair being equal to one-half the interradial dimension. Companion plates together form a sharp mouth angle with a long free margin. Marginal spinules 14, like those of adambulacrals, the innermost being somewhat enlarged and subprismatic. Actinal surface of each plate bears 8 robust, erect, sharp spines (like those of the adambulacral plates) in an irregular interradial row, with 1 or 2 odd spines in the corner adjacent to first adambulacral. There is great variation in the arrangement of these spines. Often there is a series of 4 parallel with the furrow margin, and a row of 3 to 5 extending thence to outer end of plate, decreasing in size outward. Margin of plate (excepting toward furrow) is lined with an irregular series of large, robust, subprismatic, or often subspinose granules. The odd actinal interradial plate adjacent to the outer end of the combined mouth plates bears 6 to 9 spines.

Madreporic body is circular, convex, with irregular striations. It is situated near the center of disk, about 12 mm. from anal opening (one-seventh distance from center to edge of disk).

In a medium-sized specimen examined the abactinal plates of the radial and either adradial series are distinctly 6-lobed. The other plates of the papular area, on either side of these, rapidly lose the lobed character. Near the primary radial plates the lobes become detached and form internal short radiating ossicles (4 to a plate) joining neighboring plates. The lobed plates touch each other by the lobes, usually only 4 lobes (2 on either side of plate) being sufficiently enlarged to impinge regularly on those of laterally situated plates. Each radial plate is thus joined to 2 adradials on each side. There are 5 large polian vesicles, and 5 conspicuous, distally bifid intestinal coeca. Interradial septa single, uncalcified.

Color in life: Abactinal surface bright cadmium yellow except the radial papular areas, and a circular area about the anus (bounded externally by the madreporic body), which are bright madder pink. The erect spines are whitish. Dorsal surface of superomarginal plates, except on outer third of ray, madder pink. The abactinal area of pink is lanceolate in shape, and about the border grades into the yellow area. The enlarged granules here are pink, while the rest of the plate is yellow. Many of the granules are deeper colored than the general tint. Actinal surface whitish.

Variation and young: This species is subject to a certain amount of variation which appears to be mainly due to age. There is represented in the collection every gradation in size from the smallest,

with a major radius of 32 mm., to a giant with major radius 217 mm. The principal difference in general shape is a more rounded interbrachial arc in the young, which gives a greater prominence to the ray. The adults have a large, heavy disk and relatively less prominent though not shorter rays. The spinulation of superomarginals is weak or lacking in the small individuals, but the erect spines on the abactinal plates are often rather more conspicuous, though not necessarily so numerous. These abactinal spines are well developed in all specimens, and are thoroughly characteristic of the species. On account of the more reduced disk in small specimens, the radial papular areas with their special armature and larger granules are rather more extended than in medium-sized and adult specimens. Young examples also have fewer adambulacral spines, both furrow and actinal. Inferomarginal spines are much fewer in young. The following table records a few of the more important differences due to age. Not all specimens are here noted.

Table showing variation of specimens.

Station.	Major radius.	Minor radius.	Number of superomarginal plates to side.	Number of superomarginal plates in contact on ray.	Abactinal spines to each radial area.	Adambulacral armature.		Inferomarginal spines.	Superomarginal spines.
						Furrow spines.	Actinal spines.		
4077a	32	13.5	31	11	Well developed	7-8	2-3	3-4, short	Absent.
4077b	47	16.5	45	18	do	8-10	2-3	3-5	A few tubercular granules.
4077c	51	18	48	18	28-30 to each radius; 2-2.5 mm. in length.	8-10	2-3	3-5	Do.
4077d	56	19	50	18-19	do	8-10	2-3	4-6	Nearly absent.
4077e	59	20	50	18	do	8-11	2-3	4-6	Scattered conical tubercles.
4077f	66	23	54	19	do	9-12	2-4	5-10	2-3 conical tubercles.
4077g	68	22	54	20	do	7-11	2-3	5-10	Do.
4098	74	24	64	24	Very well developed, 50-55 in each radius.	8-12	2-4	5-10	2-4 conical tubercles.
4077h	85	27	64	24	18-20	9-12	2-4	5-10	2-4 poorly developed tubercles.
4077i	87	30	60+	22	30-35	9-12	2-4	5-10	2-3 spinules.
4077j	90	30	68	24	35-38	9-12	2-4	5-11	Do.
4098a	103	37	74	24	25-38, large	8-13	2-4	5-11	Do.
4077k	135	45	92	31	20-22	9-14	2-4	5-13	Do.
4077l	143	55	96	31.5	45-55	8-13	2-5	Maximum 15.	2-4 spinules.
4077m	.....	65	.....	.....	50, average	9-15	2-5	Maximum 15.	Mostly 4.
3938, type	202	84	90-94	23	43, average	9-15	2-7	Average 12-20.	2-4 larger spinules.
4102	217	95	106	29	25-40	Max. 15	2-8	Average 15-30.	Do.

<sup>a</sup> Arm tip injured.<sup>b</sup> Arm tip gone.

Localities: Type (no. 21166, U. S. National Museum) from station 3938, vicinity of Laysan Island, 148-163 fathoms, white sand and broken shells; bottom temperature, 60.3°. Taken also at the following stations, in all, 20 specimens:

## Record of localities.

Station.	Locality.	Depth.	Nature of bottom.
3838	South coast of Molokai Island	Fathoms. 92-212	Fine grayish-brown sand.
4074	North coast of Maui Island	78-85	Coral sand, foraminifera.
4077	do	99-106	Fine coral sand.
4079	do	143-178	Gray sand, foraminifera.
4098	do	95-152	Coral sand, foraminifera, rocks.
4102	do	122-132	Fine gray sand, foraminifera.

This is the most striking species taken by the expedition, and is remarkable alike for its beautiful coloring and the large size of mature individuals. It is apparently rather common on sandy bottom between 78 and 178 fathoms.

*Calliderma* may be distinguished from other genera of the Goniasterinæ by the prominent, mobile spines on the ventral plates, as well as by the broad disk, and attenuated rays, composed only, on the distal part, of the marginal plates. From its only known living congener, *Calliderma emma* Gray,

the present species is distinguished principally by the erect and prominent spines of the radial series of the abactinal surface of disk. The following differences may or may not be constant: *C. spectabilis* has rather narrower and more numerous superomarginal plates, more prominent adambulacral spines (both series), and the superomarginal, inferomarginal, and actinal intermediate spines appear rather large. *Spectabilis* is undoubtedly closely related to *emma*, which hails from Japan. When described by Gray the locality of this species was unknown, but a specimen was subsequently found in a bottle of insects from Japan. (Perrier, *Rév. Stell.*, p. 226.)

Genus **CALLIASTER** Gray.

*Calliaster* Gray, *Ann. N. H.*, vol. VI, 1840, p. 280. Type, *Calliaster childreni* Gray.

**Calliaster pedicellaris**, new species.

Pl. XXVII, fig. 1; pl. XXVIII, figs. 1, 2; pl. XXXI, fig. 1.

Rays 5. R=75 mm.; r=25 mm. R=3 r. Breadth of ray between second and third superomarginal plates, 18 mm.; between fourth and fifth, 13 mm.

Rays rather long and narrow, very gently tapering to a blunt extremity, the distal superomarginals being in contact medially. The rays appear of nearly uniform width after the somewhat abrupt basal expansion is passed, although they taper slightly. Interbrachial arcs widely rounded. Lateral walls thick, vertical, abactinal surface slightly convex on disk. Disk and rays very rigid and hard.

Abactinal area is narrow on rays, being narrower beyond the fourth superomarginal than the width of a single superomarginal plate. On outer part of ray abactinal plates are reduced to a single series, the plates being separated one from another by the superomarginals, which meet in the median radial line. Abactinal plates are large, irregularly circular, those of median radial series being slightly the largest and somewhat lengthened transversely on basal portion of radial area. The plates of interbrachial angle are not so regular. On central portion of disk there are numerous small plates scattered among the larger. These are arranged in more or less of a definite circle around each "radial" plate of the primary apical system, and also partially encircle a few neighboring plates. Each primary "radial" plate bears a thimble-shaped tubercle, which is repeated on 3 succeeding plates of the median radial series, thus making a longitudinal row of 4 tubercles on the proximal portion of each radial area. Unfortunately, with the exception of a single tubercle, these are all broken from the unique specimen. The scar seems to indicate that they decrease in size outward. The other abactinal plates, with the exception of a few in interradial area which are flat, have exposed surface slightly concave, and bear in the center a low round granule often set in a special shallow pit with slightly tumid edges. Margin of all plates is surrounded by an irregular series of small, poorly defined, low, flat topped granules, either roundish or elongated. They lie flush with the level of plates and are more or less sunk in membrane, which is visible between the plates. Occasionally there are 2 or 3 series of granules, always irregular. In interspaces between the plates small papulae may be seen.

Marginal plates are massive, forming a broad, solid border to disk and rays. Each plate is distinct and tumid. The superomarginals, 15 to 16 in number from median interradial line to extremity of ray, are broader than high, and the length is about four-fifths of the chord of extreme width. They very gradually decrease in size toward extremity of ray. The 4 or 5 distal plates of each ray are in contact medially, while 4 to 6 plates centrally from these may touch by their inner edges, segregating 1 to 4 quadrate, abactinal plates. Each plate bears in the center, on the exposed tumid portion, a rigid, blunt, tubercular spine or elongated thimble-shaped tubercle which decreases in size toward tip of ray, and on the last 4 or 5 plates is reduced to a small granule (or may occasionally be wanting). The general surface of plates is smooth, except for a group of 2 to 3 small granules, just under the spine, on plates of interbrachial arc; and the margin is surrounded by an irregular, usually double, series of small, elongate, flattened granules similar to those encircling the abactinal plates. Terminal plate is large, with 3 spinules.

Inferomarginal plates are usually opposite superomarginals, to which they correspond in number. They are similar in character to the superomarginals, are tumid, and bear, each, a short, robust, blunt spine on the ventro-lateral face. On the first 3 plates there is also a similar spine on the lateral face, in a transverse series with the first. The first 4 or 5 plates have a few scattered granules in an irregular group on the lateral face, above the spines, and a similar group on the first 2 plates below the inferior

spine. The plates are also surrounded by a series of granules, similar to but larger than those of the superomarginals. Occasionally this series is incompletely double, especially along the lower margin.

Adambulacral plates are considerably broader than long, and the actinal surface is slightly raised above the level furrow margin (i. e., when animal is viewed from below). Armature as follows: (1) A furrow comb of 9 (or 8) spines, the lateral members of which are usually shorter than the other 7, which are subequal, parallel, about as long as the plate, round-tipped, slightly compressed, and untapered. The adoral end of each series overlies the aboral end of the adjacent series toward mouth. (2) On the actinal surface 2 thick, robust, cylindrical, blunt or truncate spines disposed in a transverse row. These may be very slightly tapering, and are about as long as the width of a plate. Margin of plate is surrounded by a single series of large, bead-like granules, and there are also 2 or 3 granules on the general surface of the plate.

Mouth plates are not prominent, but of fair size, elongate. The united pair form a regular projecting angle, with a long free furrow edge. Each plate is a low isosceles triangle in shape, the base to the median suture. Armature as follows: (1) A furrow series of 9 spines, the outer 6 of which are like those of the adambulacral plates and increase slightly in length toward the inner angle. The 3 inner spines are much larger and heavier, and increase in size toward the inner angle, the innermost tooth being blunt, heavy, and flattened on the actinal surface. There are thus 6 teeth at each mouth angle. (2) On the actinal surface one heavy spine, like the corresponding spine of adambulacrals, situated at about the center of plate; and a much smaller spine standing in line with it, toward the inner angle. The latter varies in size. Several large flattened granules occur near this spine. Along the edge adjacent to first adambulacral, and on outer half of median suture margin (i. e., behind the big spine) are numerous (12 to 14) large irregular granules in an irregular series.

The actinal interradial areas extend as far as the fourth inferomarginal. They are paved with large 4 to 5 sided plates, which are bordered by a row of prominent bead-like granules. Those plates adjacent to the adambulacrals are slightly convex, and as far as the third inferomarginal each bears a large 2-jawed pedicellaria, set in a special depression. Each jaw is broadly spatulate and rounded at the tip and when the pedicellaria is open fits into a special depression of the plate. Two or 3 other plates in the interradial region also bear a single pedicellaria, so that there are 19 or 20 pedicellariæ to each actinal interradial area. The majority of other plates bear 1 to 6 bead-like granules on the surface, in addition to the peripheral series, and these are usually clustered to one side, leaving most of the plate smooth.

Tube feet have large sucking disks. Ambulacral furrow is very narrow, entirely closed over by the furrow armature. Anal aperture is subcentral, very small.

Madreporic body is flat, circular, larger than any abactinal plates; situated midway between center of disk and inner edge of superomarginals.

Color in life: Abactinal area between chocolate color and Mars brown; superomarginal plates chocolate; spaces between abactinal plates in central portion of disk much darker, showing the plates in relief. Actinal surface buff pink, excepting large spines and adambulacral plates, which are cream color. Color in alcohol, dull brown, lighter beneath.

Locality: Station 4100, Pailolo Channel, between Maui and Molokai Islands, 130 to 151 fathoms, coral sand, shells, foraminifera; bottom temperature, 61°. One specimen, type no. 21167, U. S. National Museum.

This remarkably beautiful starfish evidently belongs to the genus *Calliaster*, although the other 2 known species are devoid of pedicellariæ. This feature alone will serve to distinguish the present form. It is also characterized by the following details of structure: The rays are longer and narrower than in the other species, with several distal superomarginals in contact medially; abactinal spines are fewer; superomarginal spines fewer and larger; actinal adambulacral spines 2 and very large; furrow comb of 8 or 9 spines; no enlarged tubercle on actinal intermediate plates as in *baccatus*. There are numerous minor differences which are appreciated by a comparison of figures. *Calliaster childreni* comes from Japan, *C. baccatus* from Simon's bay, Cape of Good Hope, 5 to 18 fathoms.

#### Genus GILBERTASTER, new.

Type *Gilbertaster anacanthus*, new species.

Form stellate, with a broad, slightly convex disk and wide, rounded interbrachial arc. Marginal plates prominent. No spines on abactinal, marginal, or actinal plates. Pedicellariæ very large and bivalved.

Abactinal plates flat, roundish, or not very regular polygonal in shape. A definite medio-radial row can be distinguished, the other plates being arranged in more or less parallel series, decreasing in size toward margin and tip of ray. Each plate is covered with large, close-set, flattish, very irregular valve-like granules, those about the border being smaller than the centrally situated ones. Scattered over disk and basal portion of rays are many large bivalved pedicellariæ, which are oblong in shape when viewed from above. Conspicuous papuleæ emerge singly from sutures between the plates and are generally distributed except at end of ray.

Marginal plates are conspicuous, numerous, devoid of either spines or pedicellariæ, somewhat convex. They are covered with rather large, flat, round, hexagonal or irregular granules.

Adambulacral plates massive, nearly quadrate, with a variable and irregular but not prominent armature. Armature as follows: (1) A furrow series of about 2 or 3 short, stubby, very robust spines, flattened in a horizontal plane, and with truncate or irregular tips. Middle spine is often shorter than the 2 laterals; or occasionally a very large bivalved pedicellaria stands at the margin in place of the spines. (2) On the actinal surface 8 to 12 large, irregular, depressed, spaced, quadrate and polygonal granules of different sizes, and arranged without constant order. When a suggestion of 2 irregular longitudinal series can be seen, the inner has much larger granules. Bivalved pedicellariæ frequently replace some of the granules. No prominent spines on the actinal surface of any of the adambulacrals.

Mouth plates narrow, and slightly convex actinally. Armature consists of about 5 robust furrow spines, the inner massive, blunt, and subprismatic, with flattened side to actinostome. The actinal surface is covered with granules similar to those of the adambulacrals.

Actinal interradial areas well developed, paved with large actinal intermediate plates arranged in not very regular series parallel to furrow. These plates are very irregularly subquadrate to polygonal, and are covered with heavy, quadrate, oblong, or roundish granules, the exposed surfaces of which are flat. The plates adjacent to the adambulacral are larger than the others, and each bears a large bivalved pedicellaria surrounded by a single series of granules. Other smaller pedicellariæ are scattered over the rest of the interradial area.

Madreporic body of medium size, subcircular, convex; situated one-third distance from center of disk to extreme margin. It has no striæ, but is perforated with irregular pores of conspicuous size.

#### *Gilbertaster anacanthus*, new species.

Pl. xxvii, figs. 2, 2a-2c.

Rays 5.  $R=65$  mm.;  $r=22$  mm.  $R=3r$ . Breadth of ray at base (between second and third superomarginals) 16 mm.; half way between base and extremity, 10 mm.

Rays rather long and narrow, tapering abruptly at base, and then very slightly throughout rest of distance to the blunt extremity. Disk of fair size and rays inflated. Marginal plates well rounded. No spines of any description on general surface of body. Very large, low, sessile, bivalved pedicellariæ, on actinal and abactinal surfaces but not on marginal plates.

Abactinal area is paved with close-set, flat, roundish, or not very regular polygonal plates. A definite medio-radial series can be distinguished, the other plates being arranged in more or less regular rows parallel with it, decreasing in size toward the tip of ray and margin of body. Each plate is covered with close-set, superficially flat, large, very irregular granules. Those about the border of plate are smaller than the centrally situated ones, and form a very irregular peripheral series. The central granules, 2 to 6, are elongate, roundish, or rarely polygonal, while many have grotesque outlines quite impossible to describe. On small plates in the interradial areas, there is usually only a single large central granule. The exposed surface of granules is usually very slightly rounded or convex. Scattered over the disk and basal portions of arms are many large bivalved sessile pedicellariæ, which are oblong in shape when viewed from above. They average 1.5 mm. in length and are most numerous in interradial areas, extending thence as a single series along either side of the ray, just adjacent to superomarginals. They are absent from the median radial series of plates except rarely near center of disk. Each pedicellaria is so large that it extends quite across its plate, occupying the greater part. An interrupted series of granules surrounds it. The jaws are faintly toothed or serrated on opposing faces. Those pedicellariæ half way between center of disk and margin are largest (attaining 2 mm. in length); the smallest are adjacent to superomarginals. Conspicuous papuleæ emerge singly from sutures between plates, and are generally distributed except at the very tip of ray.

Marginal plates are conspicuous, with a gently convex surface. Upper and lower series are not precisely opposite on arms; sometimes alternate. Superomarginals, 22 in number from median interradial line to extremity of ray, do not encroach much upon abactinal area, but form a rounded bevel. They are nearly quadrate in the interbrachial arc, but are longer than high on proximal two-thirds of ray, gradually becoming higher than broad toward the tip. The edge of the plate toward the abactinal area is curved. On one interradius there is a small, odd interradial plate, wedged between first superomarginals at their upper ends, apparently quite abnormal. General surface of plates is covered with rather large, flat, round, hexagonal, or irregular granules which increase in size from center toward periphery. Although low, their general surface is very slightly convex, and is smooth. In interbrachial arc the granules of the peripheral series are conspicuously smaller than the others, but on the ray they may be large, owing to the fusion of granules of the first and second series, which thus form long granules, extending from the periphery toward the center. Often long and short granules alternate. Terminal plate is prominent, subspherical, prolonged on the inner and abactinal side, covered with scattered granules.

Inferomarginal plates are equal in number to superomarginals, and encroach rather more upon actinal area than do the superomarginals upon abactinal. The 4 median plates of interbrachial arc are the largest, with a curved margin toward actinal area. Covering of plates very similar to that of superomarginals. In one interradius there is a pedicellaria at outer and upper corner of the second inferomarginal. No others are present on either series of marginals.

Adambulacral plates are massive, nearly quadrate, with a variable and irregular armature. Furrow margin is nearly straight, but abruptly curved at either end of the plate. Armature as follows: (1) A variable number of furrow spines—usually 2 or 3—short, stubby, very robust, and flattened (in horizontal plane) with truncate or irregular tips. Middle spine is sometimes much shorter than the 2 laterals, even becoming reduced to an enlarged granule. Less commonly there are 4 spines, subequal or one much smaller. (2) First adambulacral plate has a giant pedicellaria (similar to those of abactinal surface) on the actinal surface but flush with the furrow margin, extending the whole length of plate and entirely superceding the furrow spines. Four out of the 10 second adambulacrals possess it also, but in this case a few additional furrow granules or irregular tubercles also are present. These pedicellariæ are also present on numerous other adambulacrals, but are not so large, and in all cases where present the furrow armature is in consequence reduced in size, usually to flattened upright granules or irregular spinules. Pedicellariæ occasionally are set obliquely on plate. Rest of actinal surface is covered with about 8 to 12 large irregular quadrate and polygonal granules of different sizes, and arranged without constant order. When a suggestion of 2 irregular longitudinal series can be seen, the inner has much larger granules. An enlarged granule with a swollen end is usually present just aborad to the end of the pedicellaria.

Mouth plates slightly convex actinally, the united pair rather narrow, with an extensive, angular, but rounded furrow margin. Armature stout, composed as follows: (1) Furrow spines 5, the inner massive, blunt, subprismatic, with flattened side to actinostome. The next two are shorter and weaker, flattened or prismatic, with a rounded tip. The 2 outermost are shorter still and thicker, not constant as to shape, usually irregular. (2) Actinal surface is covered with granules. A series extends along margin of median suture. These are largest, are flat, subquadrate, or pentagonal, irregular, and diminish in size abruptly at inner end of plate, the series terminating a short distance from the teeth. Another series follows margin adjacent to first adambulacral, and is continued inward parallel with furrow series, the latter portion containing a few compressed, upright, round-tipped granules, irregularly disposed. Several small granules are present between the inner ends of companion superficial series.

Actinal interradial areas well developed, paved with large actinal intermediate plates arranged in series parallel to ambulacral furrow. Those adjacent to adambulacrals are largest and most regular, being subquadrate save for the outer margin, which is usually angular or rounded. They extend to the fifteenth inferomarginal, or three-fourths length of ray, while other intermediate plates do not extend beyond basal fourth of ray, being smaller and irregularly polygonal in shape. The outer portion of the series adjacent to adambulacrals is interrupted by the inferomarginals touching the latter, thus separating the intermediate plates. On the ray these pedicellariæ are not present on every plate. Each is surrounded by heavy, quadrate, oblong, or roundish granules in a single series, with indications occasionally of an incomplete intermediate series of small granules between successive plates. There

are 12 to 15 pedicellariæ, about half the size of those already described, scattered over the remainder of the interradial areas, the plates of which are covered with closely placed, flat, irregular granules similar to those of abactinal plates. Granules surrounding pedicellariæ are raised slightly above the level of the others.

Madreporic body of medium size, subcircular, slightly convex, situated one-third distance from center of disk to extreme margin. Perforated with coarse, irregular holes; no striae.

Color in life: Dull yellow on dorsal surface, brightest on marginal plates; central part of dorsal area with a brownish cast. Actinal surface a pale Naples yellow with a brownish suggestion.

Locality: Station 4041, west coast of Hawaii Island, 382-253 fathoms, gray mud, foraminifera; bottom temperature 41.6°. One specimen, type no, 21168, U. S. National Museum.

The peculiar large bivalved pedicellariæ of this species remind one very strongly of *Hippasteria*, but the absence of spines and the structure of the skeleton are more like *Tosia*. The very unusual flat ossicle-like granules are unlike those of any goniasterid with which I am acquainted. *Gilbertaster* appears to be allied to some of the Hippasterinæ, particularly to *Cryptopeltaster* from off the California coast. The latter genus is undoubtedly a member of the Hippasterinæ. I am inclined to regard the present form as intermediate between the Goniasterinæ and Hippasterinæ, and have consequently placed it provisionally at the end of the former subfamily. It might be considered with almost equal propriety an aberrant member of the Hippasterinæ.

This genus is named for Dr. Charles Henry Gilbert.

#### Subfamily HIPPASTERINÆ Verrill, 1899.

Hippasterinæ Verrill, Revision of Certain Genera and Species of Starfishes, with Descriptions of New Forms. <Trans. Conn. Acad., vol. x, 1899, p. 174.

#### Genus *EVOPLOSOMA*, new.

Type *Evoplosoma forcipifera*, new species.

General form that of *Hippasteria*, which it resembles also in the ossicles and spines; but the whole test (both ossicles and spines) is overlaid by soft fleshy membrane, which in life completely hides the outlines of plates. Abactinal and actinal pedicellariæ erect, with rounded spatulate denticulate blades.

Abactinal surface paved with small roundish plates, interspersed with still smaller roundish secondary plates, bearing smooth or rugose granules sheathed in pulpy membrane and erect rigid spines and spinules, the former partially encased in membrane, the latter wholly. Spines and granules on marginal and actinal plates of the same character as the abactinal. Furrow spines remarkably thin and compressed, especially adorally, 3 or 4 to the plate, and with expanded chisel-like tips. Actinal adambulacral spines very robust, curiously expanded at the tip, and often gouge-shaped; usually single with an accompanying large spatulate "sugar-tongs" pedicellaria.

While this genus is undoubtedly closely related to some species of *Hippasteria*, the persistent, and in life soft pulpy membrane which covers the whole test will serve at once to distinguish it. This membrane invests each granule individually, hiding the calcareous part and causing the granulation to have a crowded, soft, warty appearance. From this surface the conical spines and pedicellariæ raise themselves in a short bristling armature. The whole animal, as in *Hippasteria*, is very rigid. When the test is dried the membrane shrinks greatly, and the roughened granules are easily seen, then appearing separated. But in life this is not the case because the membrane investment fills up all the intervening space, causing the granules to appear very much larger. The high pedicellariæ are unlike those of typical *Hippasteria*, although easily derived from them by slight modification.

Prof. A. E. Verrill agrees with me that this species constitutes a new genus.

#### *Evoplosoma forcipifera*, new species.

Pl. xxvi, figs. 5, 5a-c; pl. xxvii, figs. 4, 4a-b; pl. xxix, fig. 3.

Rays 5. R=56 mm.; r=24 mm.; R=2.3 r. Breadth of ray at base, between third and fourth superomarginals, 11 mm.

Disk large, pentagonal, inflated, narrowing abruptly into slender, tapering rays, which end in a blunt point. Body bristling all over with short, stout, conical spines. Disk very distinct from rays, which appear as if attached to its corners. Integument stout; whole animal rigid. Marginal plates not distinct. Interbrachial arc very wide, straight, not curved in median portion.

Abactinal area conspicuously inflated about border, and paved with rather small round plates, among which are smaller secondary roundish plates. They are immersed in a tough membrane, and

the whole of the abactinal and actinal surfaces and marginal plates are covered with variously sized spiniform granules, each invested with a soft, thick, and pulpy membrane which completely hides the granules, giving the appearance of a crowded, soft, warty, irregular, granulation. These fleshy granules are round- or flat-topped, and so crowded that they press each other out of shape. They completely hide the outline of the abactinal plates. Scattered over abactinal surface are many short, stout, sharp, erect, conical spines, giving the whole surface a bristling appearance. The largest are 2 mm. long, and they decrease in size toward the margin. Scattered among them are many intermediate, sharp, conical tubercles of several sizes, evidently specializations of the immersed granules. The pulpy membrane rises upon the base of the spines, but is not evident toward the tip. Spines are arranged in 2 or 3 irregular rows on ray, and decrease very irregularly in size toward its extremity. Over all the disk except a very limited and narrow interradiial region long, conspicuous papulae emerge from the reticulated covering. They are scattered around the plates; absent from rays. On interradiial areas of disk are a few large 2-jawed upright pedicellariae. These are sunken in special pits, have broad, even, rounded, often notched, spatulate jaws, which, however, possess no especial depression into which they fit when opened.

Marginal plates are large, but not conspicuous. The 2 series correspond in number and are opposite. Superomarginals, 15 in number from median interradiial line to extremity of ray, are confined to side wall of body in interbrachial arc, but encroach more and more upon abactinal areas as they proceed along the ray. On outer part of ray their breadth very nearly equals height. In interbrachial arc the length is a trifle greater than height (or width). Transverse sutures and that separating the 2 series are easily seen. The line of demarkation between the marginal and abactinal plates is not clearly evident. On disk the superomarginals bear 3 stout, rigid, sharp, conical spines, stouter than those of the dorsal integument, disposed in a transverse series on a median tumid portion of the plate. At base of ray these become reduced to 2, and on outer portion of ray to but one, which stands on a sort of boss where the lateral and dorsal superficies of the plate meet. First superomarginal usually has slightly shorter spines, and 3 or 4 of them are grouped in the center of plate, with a number of subsidiary conical granules surrounding them. A marginal series of rather regular, 4-sided to subcircular flattish, fleshy granules borders each plate—save the upper edge. Within this is a second series of larger spherical to subconical granules, less regular, surrounding the base of the tumidity which bears the spines. On outer portion of ray the transverse portions of second series of granules are absent. First and second plate usually have a pedicellaria similar to those of abactinal surface near the middle of the lower side just above the peripheral row of granules.

On disk the inferomarginals are slightly larger than corresponding superomarginals, are quadrate, about as broad as high, and form an evenly curved margin to actinal area, upon which they encroach. They are tumid like the superomarginals, the tumidity becoming more pronounced on ray, on the proximal plates of which are 2 (usually 3 on innermost plate of ray proper) rigid spines, similar to those of superomarginals, and similarly placed. On outer third or half of the ray these are reduced to a single spine. On first 3 inferomarginals there are 7 shorter spines, with several enlarged granules, scattered in an irregular quadrate group. Fleshy granules, like those of superomarginals, cover the remaining surface of the plates. The inner or lower edge of the plates is not evident superficially, the granules being continuous with those of actinal interradiial areas. In one interradius there is a small pedicellaria, like those described for superomarginals, situated near the upper border of each of the 2 median inferomarginals.

Ambulacral furrow rather narrow. Outlines of adambulacral plates not evident superficially on account of the fleshy granules. Plates are slightly longer than wide, with a convex margin to furrow. Furrow spines are 6 on first plate, 5 on second, and 4 or 3 on the rest. They are long, stout, strongly compressed, with broad subtruncate or rounded tips. They resemble broad chisel or narrow hatchet-blades in shape, and become thinner toward the tip. Where there are 4 spines the aboral is shortest, and varies much in shape, resembling usually a wedge. The other 3 are subequal, or the median slightly the longest. Often a spine appears as if partially twisted on its long axis, or the broad spatulate blade may be a trifle concave on one face like a scoop. The 2 lateral members are usually broader at the tip than the median. In the middle of the actinal surface of plate stands a solitary, remarkably heavy, rigid, upright spine, shorter than furrow spines. Its base is cylindrical, but the end flares more or less, and the outer aboral face is concave like a gouge; the tip is rounded, subacute, or blunt. Frequently the tip appears somewhat 3-sided, one side concave, and the others flat or slightly rounded.

There is great variation in the details of this spine in the single specimen. On adoral side of plate, close to furrow margin, is a very large, upright 2-jawed pedicellaria, the valves being broad and shaped something like a pecten shell, only more irregular. Frequently the edge is notched, and one edge slightly concave, the other correspondingly convex. On the ray the pedicellariae decrease in size, and are very broadly spatulate with a more contracted base than have those of disks. Outer side of plate is beset with 5 to 6 flesh-covered, irregular roundish or 4-sided granules, 1 or 2 of which, on the 4 to 5 proximal plates, are larger than the others.

Mouth plates large, but not prominent actinally. Plates are broad, the combined pair with an extensive and angular rounded furrow margin. Armature as follows: (1) A furrow series of 8 much flattened, abruptly round-tipped, spatulate spines, which become thinner toward the tip like a wedge. Their bases are united by a delicate web. They are more regular than the adambulacral furrow spines and a trifle smaller, except the inner 2, which are large, very broad, and hatchet-like. The innermost tooth is largest of all. (2) Back of furrow spines the actinal surface is bare for a short distance, the remainder of surface being covered with the characteristic granules, which are not crowded, and which increase in size toward outer end of plate. In center of actinal surface is a single upright pedicellaria, similar to, but smaller and slenderer than those of adambulacrals. First adambulacral is larger than the rest, with 6 furrow spines, and its actinal spine reduced in size. Actinostome small, entirely roofed over by the large spines.

Actinal interradial areas are large, forming a nearly equilateral triangle, bounded by the first 2 inferomarginals; a single series of intermediate plates extends, however, as far as the fifth inferomarginal. The plates are roundish and entirely obscured by the numerous compactly placed, round or irregularly polygonal skin-covered granules which shrink up when dried and allow the plates to be seen (pl. xxix, fig. 3). From 30 to 45 stout, erect, rigid spines, smaller than those of the adambulacrals, and a trifle heavier than those of the inferomarginals, are disposed in irregular chevrons over interradial area with the exception of a small space immediately outside of mouth plates. These spines are short, conical, with grooved, 3- or 4-sided tips, much resembling some sort of a drill. When the specimen is dried they are seen to correspond, about 1 to a plate. The calcareous portion of the granules is rugose or roughened. A pedicellaria, similar to those already described, is situated near outer end of mouth plates, and another about the middle of interradial area.

Madreporic body small, convex, with coarse, convoluted striations; situated a trifle nearer center than midway between latter and margin of disk.

Tube feet large, with large sucking disks.

Color in life, pinkish orange.

Locality: Station 4186, east of Kauai Island, 682-508 fathoms; gray sand, foraminifera; bottom temperature 38.1°. One specimen, type no. 21169, U. S. National Museum.

This species is readily distinguished by the curious fleshy investment of all the granules of the body, as well as of the base of the spines. The photographic figure of this species is from the dried specimen, in which the membrane has greatly shrunk.

#### Subfamily LEPTOGONASTERINÆ Perrier, 1894.

Leptogonasterinæ Perrier, Exp. Scientif. du Travailleur et du Talisman, etc., Echinodermes, 1894, p. 252.

#### Genus ANTHENIASTER Verrill.

*Antheniaster* Verrill, Trans. Conn. Acad., vol. x, Aug., 1889, p. 173. Type, *Anthenoides sarissa* Alcock.

#### *Antheniaster epixanthus*, new species.

Pl. xx, fig. 3; pl. xxvi, figs. 1, 1a-c; pl. xxix, figs. 1, 2; pl. xlix, fig. 1.

Rays 5.  $R=90$  mm.;  $r=47$  mm.  $R=1.92$  r. Breadth of ray, between first and second superomarginals, 47 mm.; between fifth and sixth, 25 mm.

General form is flat and depressed. Disk large, pentagonal, slightly inflated in most specimens. Rays short, broad, tapering, flat, acute, but not narrow-pointed. In smaller specimens the rays are much longer. Interbrachial arcs very wide, rounded or occasionally a trifle angular. Lateral wall, or margin, rounded-vertical in large specimens; rather angular in the interbrachial arcs of smaller specimens, but becoming vertical on outer part of ray, which is then quadrate in section. The whole animal is covered with a moderately thick, tough but soft membrane or skin, which obscures the out-

lines of most of the plates in the living and alcoholic specimens. When dried, the membrane shrinks very much, and on the dorsal surface reveals a sparse and very minute granulation. Granules of marginal and actinal plates are coarse and conspicuous in the dried state, but are not very conspicuous in the living or alcoholic specimens on account of the pulpy consistency of the skin.

Abactinal surface is subplane to slightly convex, covered with a wrinkled, rather thick membrane which reveals the plates beneath when dried. In each median interradiial line there is a sharp crease extending inward toward center of disk, while similar lines extend toward center of radial area from each suture between superomarginals. Everywhere the skin is traversed by fine creases. Radial areas are conspicuous by the black papulæ which have passage at corners of hexagonal plates, and thus indistinctly mark out their form. Papulæ wanting on median interradiial region. Plates are further revealed in fresh specimen by creases which radiate from papular pores. The fine granulation is not apparent in the undried state. Pedicellariæ wanting on dorsal surface. If the skin is stripped off (which is done with difficulty), the arrangement of plates is then easily seen; or the specimen may be dried. Plates are polygonal and rather irregular. A fairly regular series extends along median radial line, the remainder being arranged parallel to this. Median series does not reach tip of ray, the outer 6 or 7 superomarginals of either side being in contact medially. The other series do not extend so far as the median, but end one after another in conformity with the taper of the ray. External to median radial series on each side is an irregular series of much smaller plates which extend but a very short distance beyond the base of the ray, where they die out gradually. The plates of next series external to this are large as the median radial, and are adjacent to them after the disappearance of the smaller intermediate series. The third longitudinal series consists of even smaller and more irregular plates than the first or intermediate series. (This series is not apparent in largest specimens, and when present it does not extend so far distad as the other intermediate plates.) Fourth series as large as second. Opposite the fourth superomarginal one can count 6 or 7 longitudinal rows at either side of the median radial series. Occasionally the smaller intermediate plates form a partial series around the larger plates, but in this case they are smaller than the longitudinal series of intermediates. No definite arrangement over center of disk, which is paved with rounded or subpolygonal, large and small plates mixed together. Interradiial plates are regular in type—hexagonal to quadrate—but may be irregular in smaller specimens. If abactinal area is treated with caustic potash and viewed from the internal (or coelomic) side, some of the smaller intermediate plates (not those of the longitudinal intermediate series, but still smaller plates) are seen to form short, connecting, radiating ossicles between larger plates of the median radial area at base of ray nearly to center of disk. Their arrangement is irregular, however, and some of the smaller plates of the disk are rudely substellate. This point is, however, not at all evident when the plate is viewed from the dorsal side. The so-called connecting ossicles appear merely as irregular small plates between the larger polygonal ones. In large specimens these smallest intermediate plates are scarce; and they are by no means constant in number or position in the medium-sized and small specimens. But the presence of an intermediate incomplete series of secondary plates at either side of the median radial series is constant.

Marginal plates are well developed. Superomarginals, 20 in number from median interradiial line to extremity of ray, are wider than long, and form an arched border to body. In a few smaller specimens the inferomarginals extend laterally slightly beyond superior series on disk. In this case the superomarginals form more of an arched bevel. They are covered with tough membrane, in which are embedded 8 to 20 subspherical granules spaced over the central portion of plate. These are absent from outer half of ray. The first superomarginal is slightly shorter than succeeding 4 or 5.

Inferomarginals correspond in number to superomarginals, but are not always exactly opposite to them at base of rays. They are much broader than high, and encroach conspicuously upon actinal area, being covered with numerous scattered granules imbedded in membrane. These increase in size toward outer edge of plate, and are largest on the lateral face of ray, where they are as large or slightly larger than the granules of superomarginals and decidedly more numerous and close-set. Terminal plate prominent, pentagonal, armed with 3 terminal, thimble-shaped granules.

Adambulacral plates longer than wide, with a faintly convex furrow margin. Armature consists of 7 (occasionally varying to 6 or 8) short, blunt, slightly compressed spinelets, which form a radiating palmate series and are covered with membrane, which as a sort of web, unites them for a short distance above the base. Usually the end spinelets are much shorter than the median, the whole forming a rather regular graduated series. Actinal surface of plate, like remainder of body, is covered

with membrane, so that outlines of plates are wholly obscured except when in a dry state. (Compare figs. 1a and 1b, pl. xxvi.) A definite crease or line in the membrane runs from the furrow obliquely outward toward the margin of body. These wrinkles separate each adambulacral plate, and every second or third line is confluent with the suture between 2 inferomarginals, while the intermediate lines end between the furrow and margin. Actinal surface of adambulacrals bears 6 to 8 subspherical granules of unequal size, disposed in an irregular longitudinal series along the middle of plate. They are covered by thick membrane and are not very conspicuous until animal is dry. (Pl. xxvi, fig. 1b.) On outer half or third of ray these are replaced by a single, stout, short, tapering spine, exceeding in length the furrow spinelets, which are here quite short. A few plates bear, near the adoral margin, between the furrow series and granules, a single rather long 2-jawed pedicellaria, about as long as the nearest furrow spinelet. Each jaw is narrow spatulate and curves slightly, like a pair of tongs, to meet its companion.

Mouth plates are large and prominent actinally, with a very extensive furrow margin. Furrow spinelets 1f, stout, the outer ones similar to the adambulacral furrow spinelets, but the 2 or 3 inner larger and heavier. Actinal surface is armed with prominent granules, subspherical to thimble-shaped, arranged in an irregular series parallel to median suture, and another continuing the linear series of adambulacrals. Numerous much smaller granules are scattered here and there.

Actinal interradial areas are covered with membrane, which is lined with fine creases or wrinkles, as already noted. The plates are irregularly polygonal or roundish, and are arranged in chevrons, decreasing in size toward the margin. They bear a central group of subspherical or low thimble-shaped granules, the rest of exposed surface being beset with smaller, widely spaced granules. The series adjacent to adambulacrals usually bears 3 to 10 larger granules, the next series 3 to 6, and the other plates 1 or 2 such.

Madreporic body is large, hexagonal to subcircular, situated about one-third distance from center to extreme margin. Its exposed surface is flat and sunken a trifle below the level of the surrounding membrane except in the dried state. Striations fine, radiating.

Anal opening subcentral, surrounded by 5 plates larger than their neighbors. The aperture is guarded by about 8 tooth-like granules. Tube feet with large sucking disks.

Color in life: Dorsal surface deep cadmium yellow to cadmium orange; lower surface cream color to cadmium. In alcohol, dull light brownish to deep brown.

Variations: There appears to be a dimorphism in this species. Some specimens (in the majority) have longer, slenderer rays than others. Superficially they would be taken for a different species, but I am unable to find any other correlative character by which to separate them. The type specimen is neither the one extreme nor the other, but is rather short-rayed, however. The following table of measurements (in millimeters) will give an idea of the difference:

*Measurements of specimens of Antheniaster epixanthus.*

Station.	Major radius.	Minor radius.	Ratio.	Supero-marginals.	Width of ray between second and third supero-marginal.
	<i>mm.</i>	<i>mm.</i>		<i>no.</i>	<i>mm.</i>
3813	93	50	1.9-	17	43
4080 (type)	90	47	1.92+	20	40
4115	69	40	1.74	15	34
4080	96	42	2.3	19	35
4080	77	32	2.4	20	28
4081	90	35	2.57	22	29
4081	65	24	2.7	18	20

The presence of pedicellariæ on adambulacral plates is also subject to great variation. In the type there are only a few scattered along the base of ray, and on the largest specimen none are to be found. On the other hand, a medium-sized specimen of the long-rayed phase has 4 to 12 on each adambulacral series of disk. At first this might appear of specific value, but pedicellariæ are either very few or absent from all the other long-rayed specimens, except one which is intermediate between the extremes.

Localities: Type (no. 21170, U. S. National Museum) from station 4080, north coast of Maui Island, 178-202 fathoms, gray sand and foraminifera; bottom temperature 56.4°. Taken also at the following localities, a total of 13 specimens:

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
		<i>Fathoms.</i>	
3813.....	South coast of Oahu Island.....	264-183	Coral sand, lava specks, shells.
4081.....	North coast of Maui Island.....	202-220	Gray sand, foraminifera.
4082.....	do.....	220-238	Do.
4084.....	do.....	253-267	Fine gray sand.
4115.....	Northwest coast of Oahu Island.....	195-241	Coral sand, foraminifera.

*Anthenoides*, *Leptogonaster*, and *Antheniaster* are very closely related. The arrangement of the dorsal plates appears to be essentially the same in the three genera, which are likewise characterized by a granulous membrane. The type of adambulacral armature of *Leptogonaster* is essentially that of the distal portion of the ray of *Antheniaster epixanthus*, and the pedicellariæ are strikingly similar, these being reduced to the elongate variety in *Antheniaster*. The dorsal membrane of the latter is not so granulous as in *Leptogonaster*, but is thicker, at least in the Hawaiian species. The mouth plates are prominent, but more heavily covered with membrane than in *Leptogonaster*, and likewise bear more granules. These three genera do not appear to belong under the *Goniodiscidinæ*, which are probably more nearly related (so far as *Goniodiscides* is concerned) to the *Pentacerotidæ* than to the typical *goniasterids*. I have accordingly placed *Antheniaster* in Perrier's *Leptogonasterinæ*. This subfamily, is of course, closely related to the *Goniasterinæ*, and not, as its author believed, to the *Mimasterinæ* or *Odontasteridæ*. I am indebted to Prof. A. E. Verrill for the generic determination of this species.

Subfamily GONIODISCIDINÆ, new name.

*Goniodiscinæ* Sladen, Challenger Asteroiden, 1889, p. 321. (*Leptogonaster* is excluded.)

Genus GONIODISCIDES, new name.

*Goniodiscus* Müller and Troschel, System der Asteriden, 1842, p. 57. Emended by Perrier, Révision des Stellérides, 1875, p. 229. Type, sens. nov., *Goniodiscides sebæ*.

This genus is equivalent to that long known as *Goniodiscus*. Under existing rules of nomenclature *Goniodiscus* is untenable because it was proposed by Müller and Troschel to include previously described genera of Gray (*Anthenea*, *Nectria*, *Tosia*), as well as species unknown to Gray. If this group had really constituted a genus the oldest name, *Anthenea*, should have been used. Likewise the type (first species) of *Goniodiscus* is the same species, under a different name, as the type of Gray's *Anthenea*. Müller and Troschel included the following species under their *Goniodiscus*: *Pentagonulus* [*Anthenea*], *sebæ*, *placenta* [*Tosia*], *regularis* [unknown], *pleyadella*, *ocelliferus* [*Nectria*], *cuspidatus*, *mammillatus* [*Tosia*], *capella* [since made the type of *Ogmaster* v. Martens]. This left *sebæ*, *regularis* (?), *pleyadella*, and *cuspidatus*. *Goniodiscus* has subsequently been used for these species, but since the name was originally applied to a composite group and was a synonym as soon as made, it should be discarded for all time. As there appears to be no subsequent name<sup>a</sup> available, I propose *Goniodiscides*, with *Goniodiscides sebæ* as type.

***Goniodiscides sebæ* (Müller and Troschel).**

Pl. XIX, fig. 3.

*Goniodiscus sebæ* Müller and Troschel, System der Asteriden, 1842, p. 58.

An example of this curious species, the first from the Hawaiian Islands, was taken by Mr. H. W. Henshaw at Hilo, on the windward side of the island of Hawaii. (Accession no. 42800, U. S. Nat. Mus.) No specimens were secured by the expedition of 1902.

<sup>a</sup> *Melopaster* Sladen (Monog. on Brit. Fossil Echinod. from Cretaceous, II, Asteroiden, pt. II, <Pal. Soc. Monog. 1893, p. 13) is near this genus, but is hardly identical, as has been claimed. (Valette, Note sur quelques Stellérides de la Craie Senonienne du Dép. de l'Yonne. <Bull. Soc. l'Yonne, LVI, 1902, p. 7.)

Concerning the capture of this specimen, Mr. Henshaw has sent me the following notes: "They are by no means rare in a small inlet some three miles south of Coconut Island. If I remember rightly, all I found were under stones in shallow water, two or three feet deep. In other words, so far as I observed it, it was a littoral, shallow water species." This is the only species of starfish, so far as I am aware, that may be collected along shore in the islands, unless *Ophidiaster lorioli* be excepted.

This specimen agrees very well with the original description of Müller and Troschel, and with the notes given by de Loriol (Mém. de Société Phys. et d'Hist. Nat. Genève, xxiv, 1885, p. 48). De Loriol also gives a good figure (op. cit, pl. xv, fig. 6) with which our example shows a few unimportant points of difference.

Form pentagonal, the sides of disk only very slightly curved inward.  $R=29$  mm.;  $r=23.5$  mm.  $R=1.23r$ . As noted by de Loriol there are 14 supermarginals to a side, or 7 to the "ray", instead of 6, as stated by Müller and Troschel. The ultimate plate of each series is very small, and is wedged between the penultimate and ocular plates. There are 9 inferomarginals to the ray, the last plate being very small indeed.

The supermarginals are somewhat tumid, and are broader than high. Besides the even, fine granulation, each bears from 2 to 10 conspicuous, low, hemispherical, or subconical, tubercular granules, unevenly disposed. Inferomarginals are similarly armed. There are no pedicellariæ on any of the marginal plates. Between the 2 series of marginal plates, on the lateral wall of the body, is a row of 5 to 7 pits, each of which occurs at the junction of a dorso-ventral with the horizontal suture.

Abactinal surface is covered with a much finer granulation than the actinal, and each plate is surrounded by 6 to 8 papular areas which appear in many cases practically confluent. These areas contain 8 to 20 pores, and a cuneiform area containing about 15 to 18 pores occurs between the dorsal ends of the supermarginal plates (excepting between 5 and 6 and 6 and 7). Each abactinal plate bears near the center 1 to 3 of the tubercular granules, a few of which occur also, here and there, over the papular areas. A number of plates toward center of disk bear small bivalved pedicellariæ similar to those of *Pentaceros* and flush with the general level of the granulation. These are not very numerous and are irregularly scattered, never more than 2 to a plate. The madreporic body is raised above the general surface and is situated about one-third the distance from the center to margin. About its border are several tubercular granules. The plates toward the end of ray and adjacent to superomarginals appear to be a trifle convex, the tumidity being surmounted by the granule, or granules.

The actinal intermediate plates are arranged in chevrons and decrease in size toward the margin. They are polygonal, and covered with a coarser granulation than the dorsal plates—a granulation which increases somewhat in coarseness toward the center of each slightly convex plate, which is surmounted by 1 to 5 enlarged granules, usually of unequal size. Scattered here and there are bivalved pedicellariæ, 0.25 to 0.75 mm. in length.

The furrow spinelets are 4 to 5 in number, robust, short, truncate, slightly flattened, the adoral spinelet shorter than the others. On the actinal surface of the plate stands a longitudinal series of 2 or 3 shorter, thicker, granuliferous spinelets, with often 1 or 2 smaller granules standing in line at either end of the series. Occasionally a very small bivalved pedicellaria stands at the adoral end of the series out of line. Behind the actinal series the fine granulation of the general surface begins, decreasing in size toward outer end of plate. The furrow spinelets appear a trifle shorter and heavier than those figured by de Loriol. A few of the proximal adambulacral plates have 6 furrow spinelets.

This species has a wide range, being found in following localities: Red Sea, Moluccas, New Guinea [Müller and Troschel], Mauritius, Macassar (Celebes), Fiji Islands [de Loriol], Ceylon, Madagascar, "Eastern Archipelago" [Sladen]. Its capture in the Hawaiian Islands considerably extends its known range.

#### Family PENTACEROTIDÆ (Gray) Perrier, emend. 1884.

Pentacerotidæ Gray, Synopsis of the Genera and Species of the Class Hypostoma. <Ann. N. H., ser. 1, vol. vi, 1840, p. 275.  
Perrier, Mém. sur les Étoiles de Mer Recueillies dans la Mer des Antilles et le Golfe du Mexique, 1884, pp. 165, 168.

#### Key to Hawaiian genera of Pentacerotidæ.

- a. Marginal plates fairly distinct, defining the contour of body.  
b. Disk high; rays carinated. Large immovable spines or tubercles on the dorsal surface. Marginal plates not conspicuous.....PENTACEROS

- bb.* Disk not so high; form nearly pentagonal; marginal plates conspicuous. Erect conical tubercles on both surfaces .....NIDORELLIA
- aa.* Marginal plates hidden or inconspicuous; not visibly defining the contour of body. The abactinal plates are not superficially distinguishable in the adult. Form thick.
- b.* A pair of large marginal plates at the end of the ray. Form substellate to stellate. Test covered with globose or acorn-shaped tubercles. Papulae evenly distributed, not in definite areas. ....ASTÉRODISCUS
- bb.* Form pentagonal, biscuit-like; no large plates at end of ray. Papulae distributed in large, definite areas .....CULCITA

**Genus PENTACEROS Schulze.**

*Pentaceros* Schulze, Betrachtung der versteinerten Seesterne u. ihrer Theile, Warshau u. Dresden, 1760, p. 50. Gray, Ann. N. H., ser. 1, vol. vi, 1840, p. 276.

*Goniaster* (pars) Agassiz, Mém. Soc. Sci. Nat. Neuchâtel, t. 1, 1835, p. 191.

*Oreaster* Müller and Troschel, System der Asteriden, 1842, p. 44. Bell, Proc. Zool. Soc. London, 1884, p. 57.

The specimens of *Pentaceros* from the Hawaiian Islands have given considerable trouble, as might naturally be expected. Relying chiefly upon Prof. F. Jeffrey Bell's useful and valuable revision of the genus, "The Species of *Oreaster*" (Proc. Zool. Soc. Lond., 1884, p. 57), I have separated the form as a distinct species, whose affinities appear to be with the *Pentaceros orientalis* section. Among the species of this group it most resembles *orientalis* and *troscheli*. On the other hand, there are certain points of similarity with *P. occidentalis*. One of the difficulties lies in the fact that some specimens have the adambulacral armature disposed in 3 longitudinal series (triplacanthid), while others have but 2 series (diplacanthid). Just this state of affairs exists in *P. occidentalis* (from Mazatlan, Mexico). Bell places *occidentalis* in the diplacanthid section, but implies that occasionally a third furrow series is present. But *hawaiiensis* differs from *occidentalis* in a most important respect—that is, in its growth stages. In *occidentalis*, as pointed out by Bell and as exemplified by specimens at hand, the young are more spiny than the adult, while in *hawaiiensis* exactly the reverse is the case. In this species, if any spines are present in the young they are inconspicuous, and are confined to the median-radial line. *Hawaiiensis*, then, is probably not derived from the American form, but from the Asiatic group. In the following diagnosis a description of the type is given, but under each category of characters the more important variations are indicated.

***Pentaceros hawaiiensis*, new species.**

Pl. xxxii, figs. 1, 2, 3; pl. xxxiii, fig. 1; pl. xxxiv, fig. 3.

Rays 5.  $R=125$  mm.;  $r=50$  mm.  $R=2.5$  r. Dimensions measured on ventral side. (In 2 larger specimens the rays are relatively shorter,  $R$  equaling 160 mm. and  $r$  about 78. In still another specimen, the largest of all,  $R=188$  mm., and  $R=2.35$  r.)

Disk large, elevated, and regularly convex; about 55–58 mm. high, measured from actinal plane. This dimension varies considerably according to the inflation of disk, several specimens being much depressed. Rays well produced, rather broad at base. Actinal area plane on rays, sloping upward toward actinostome on disk.

The whole abactinal surface is marked off by trabeculae into large triangular, or on the ray often rectangular papular areas. On disk they are fairly regular, but on ray are irregular. At each angle is a large conical tubercle, there being a definite medio-radial series extending to tip of ray, and on either side 2 parallel longitudinal series, the first extending about half the length of rays, and the second not so far as the first. In interradial angle formed by the outer series of adjacent rays are 3 to 6 tubercles. The pentagon marked off by the conspicuously enlarged primary radial tubercles (apical area) is also divided into triangles, often very regularly into 10, but again irregularly. There is a variable number of smaller tubercles in this area (7 in type). All tubercles decrease in size toward tip of ray and margin of disk. Granulation consists of variously sized polygonal granules crowded together, often increasing in size as they ascend the tubercles, the spinous tip of the latter being always free from granules and the line of demarcation well defined. Granulation is finer than in either *P. reticulatus* or *P. occidentalis*, the only species with which I have been able to make direct comparisons. Numerous small slit-like pedicellariae, flush with the general surface, are thickly scattered over

the whole abactinal surface, being present frequently on the bases of the tubercles, but most numerous in the papular areas.

Superomarginal plates, 23 in number from median interradiad line to extremity of ray, are rather indistinct and are wholly without spines or tubercles of any description. Besides the granulation, which is coarser than that of the abactinal surface, and which increases in size toward the actinal surface, each plate bears 1 or 2 long slit-like pedicellariæ, larger than those of the dorsal surface but otherwise similar. Superomarginals define border of ray.

Inferomarginals, 20 in number, are confined almost wholly to actinal surface. Four or 5 on each side of median interradiad line bear a small thimble-shaped tubercle, on a slight tumidity, near outer edge of plate. (This is absent from the largest and from the 2 smallest specimens.) The granules are very irregular as to size; and on each plate there are 1 to 5 slit-like pedicellariæ scattered among them. These have jaws slightly raised above the general level, and are narrowly elliptical in shape, with truncate ends. In the interbrachial arc there are 5 or 6 roundish plates intercalated between the 2 series of marginals. (These are absent from the 2 young specimens, and much more numerous in the largest. They are present also in *P. occidentalis* but do not appear so early. In a giant specimen of *reticulatus* I find no trace of them.)

Armature of adambulacral plates is in 2 or 3 series. (1) Furrow series of 8, less often 7, flattened, round-tipped spines, the central ones much longer than the laterals and their tips broader than base. Lateral-most spines scarcely equal one-half the length of longest spines; often mere elongated granules. This furrow series forms a regular comb, with a much rounded, often angular margin. Spines are united for some distance above their bases by a delicate web. A large forceps-like pedicellaria stands at adoral end of each series, slightly actinad. Furrow series is situated much higher (abactinad) on the side of furrow than the second series, the tips of the former only reaching or extending slightly beyond the base of the latter. (2) Second series, situated more nearly on true edge of furrow, consists of 2 to 4 spines, often only 2, this latter number predominating on the outer part of ray. They are of unequal size, very irregular, but the central spine (or 2 spines if there are 4) is largest, with the tip usually broader than the base, and rounded or truncate. Lateral spines vary much, but are shorter than the median and are either oblong or leaf-like, with a straight edge to the adjacent median spine. Toward the end of ray the second series is reduced to pinched granules. (3) Third series when present consists of 2 or 3, often 4, enlarged pinched granules, with rounded tips, in an irregular longitudinal row at outer edge of plate. In one large specimen the third series is present on nearly every plate, and is well developed, but in the majority of specimens, including type, it is poorly developed, being represented by granules of rather small size. Tips of second and third series of spines crinkled.

Actinal plates covered with granules, large and small, with many bivalved pedicellariæ scattered among them. The granules increase in size toward ambulacral furrows, becoming subtubercular or subspinose in the largest specimens. These tubercles are always mobile, however.

Actinal surface of mouth plates covered by the heavy granular integument, which has to be removed before the plates themselves can be seen. These are large, and when the integument is removed, a large convexity or tumid area is seen near the aboral furrow corner, which is surmounted by 2 to 5 heavy spines, corresponding to the second series. Furrow spines 10 or 11, increasing greatly in size toward the inner mouth angle, where they are large and heavy, and many times larger than at outer end of the series, where they are similar to those of the adjacent adambulacral. (The actinal spines already mentioned vary in number, but there are never less than 2 nor more than 5.) Actinal surface (of integument) coarsely granular, with often very many pedicellariæ.

Madreporic body oval, either narrow or broad, situated outside the apical pentagonal area at a distance equal to one-half the distance from center to interradiad edge of apical area. Anus eccentric, prominent.

Color in life: Upper surface maroon, orange on the tubercles. Actinal surface light Naples yellow in the center, shading into maroon toward the periphery.

Variations: The principal variations have already been noticed. One specimen, about the size of the type, has fewer and smaller spines on the dorsal surface, the median radial line extending only about one-half the length of ray. A larger specimen has the tubercles more acorn-shaped, and covered with granules except a bare blunt point at the tip. The connecting trabeculae are likewise more prominent. The rays are longer and slenderer than in the type, but this character has no stability in this species.

Young: The smallest specimen examined ( $R=65$  mm.;  $r=28$  mm.; measured on actinal side) is destitute of all dorsal spines or tubercles, there being, along the median radial line, a series of bosses, or rounded elevations, where the tubercles later appear. No tubercles are present on the inferomarginals. Slit-like pedicellariæ are numerous on the dorsal surface, but the larger bivalved kind are not so numerous as in the adult on the ventral area. Third series of adambulacral granules is developed on most plates, the second series consisting of 2 or 3 stout elongated granules. In a specimen in which  $R$  equals 70 mm. a few conical tubercles have begun to appear along the median radial line, and 2 in the apical area. In this specimen the third adambulacral series is fairly well developed on all plates. In young specimens the papular areas are relatively smaller than in the adult, and the trabeculæ broader. The former are irregular, oval, or oblong, not triangular. In these two specimens the marginal plates are quite regular and there is no intermediate series intercalated between them in the interbranchial arc, as in the adult. All the granulation is more regular. In the largest of these immature specimens the actinal intermediate plates, roundish in shape, can quite clearly be seen, arranged in regular chevrons.

Localities: Type (no. 21171, U. S. National Museum) from station 3850, south coast of Molokai Island, 43-66 fathoms, coarse sand and broken shells, coral; bottom temperature  $71.7^{\circ}$ . Taken also at the following stations, in all, 14 specimens examined:

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
		<i>Fathoms.</i>	
3849.....	South coast of Molokai Island.....	73-43	Coarse sand, broken shells, coral.
3872.....	Auan Channel, between Maui and Lanai islands.....	43-32	Yellow sand, pebbles, coral.
4072.....	North coast of Maui Island.....	56-59	Coarse coral sand, foraminifera.
4075.....	do.....	49-57	Fine gray sand, foraminifera.

**Genus NIDORELLIA Gray.**

*Nidorellia* Gray, Ann. N. H., ser. 1, vol. vi, 1840, p. 277. Type, *Nidorellia armata* Gray.

***Nidorellia armata* (Gray).**

*Pentaceros (Nidorellia) armatus* Gray, Ann. N. H., vi, 1840, p. 277; Synopsis Starfishes, p. 7, pl. xiv, fig. 1-3, 1866.

*Nidorellia armata* Verrill, Trans. Conn. Acad., vol. 1 (2d pt.), 1867, p. 251. Perrier, Révision des Stellérides, p. 251, 1875.

*Oreaster armatus* Bell, Proc. Zool. Soc. Lond., 1884, p. 81.

Prof. F. Jeffrey Bell in his paper "The Species of *Oreaster*" records *Nidorellia* from the Sandwich Islands. This form was not found by the *Albatross* Expedition.

**Genus ASTERODISCUS Gray.**

*Asterodiscus* Gray, Proc. Zool. Soc. London, part xv, 1847, p. 75. Type, *Asterodiscus elegans* Gray. See also Ann. N. H., 1847, p. 196; Synop. Spec. Starfish, British Mus., 1866, p. 5, pl. xii, figs. 1 and 2.

This peculiar genus may be readily distinguished from others of the Hawaiian region by its thick body, short rays, and tough test covered all over with tubercles, large and small, among which are many granules, ranging down to the most minute. The general form is depressed, while the rays are blunt, and bear at the tip 2 large convex, oval ossicles, between which is set the tubercular terminal plate. *Culcita*, the only other genus closely resembling this, entirely lacks the 2 enlarged plates.

The specimen at hand differs in several important respects from both Gray's figures and description of *Asterodiscus elegans* (Synopsis, p. 5, pl. 12, figs. 1 and 2). The body is not so pentagonal, for there are distinct rays present which are more marked in this adult individual than in the young specimen of *elegans* which Gray has figured (op. cit., fig. 2). There is no distinct medioradial line of tubercles larger than the rest. Gray's description states that the tubercles of *elegans* are "flat-topped", and again, "truncate", which in nowise applies to our specimen, for here the tubercles are roundish-subconical, or acorn-shaped with a blunt point. Gray further says: The young specimens have indistinct marginal ossicula". One specimen, which is clearly adult, has both series of marginal plates quite distinct, the inferomarginals the more numerous; while in 2 young specimens ( $R=10$  mm.) the marginal plates are as distinct as in any goniasterid, the animal resembling, at first glance, a starfish

of the *Pentagonaster pulchellus* type. There is, however, a single series of plates between the upper and lower marginal series.

On the whole our specimen appears to belong to a different species. *Asterodiscus elegans* comes from off Samboagan, Philippine group (Challenger), and from northeast coast of China (Perrier, Rév. Stell.).

***Asterodiscus tuberculosus*, new species.**

Pl. xxvi, figs. 2, 2a; pl. xxviii, fig. 3; pl. xxxii, figs. 3, 4; pl. xxxiii, fig. 2; pl. xxxiv, 1, 2.

Rays 5.  $R=69$  mm.;  $r$ =about 40 mm. ( $r$  being variable).  $R=1.7r$ . Breadth of ray at base, about 45 mm. Rays short and broad, tapering to a blunt extremity; rather unequal as to width and length. Disk large, somewhat inflated. Interbrachial arcs widely rounded. Side of body fairly high, but well rounded.

Abactinal surface is covered with numerous large tubercles shaped something like a miniature acorn, or like a pointed egg standing on its blunt end. A fairly regular median radial line of them is present with an adradial series, but beyond these the tubercles are too irregular to form definite series. Each tubercle stands on a slight prominence of the test, and its base is surrounded by a circle of small, regular, bead-like granules, very ornate in appearance. These tubercles are largest near the extremity of rays and in center of disk. Scattered thickly among the tubercles, forming indefinite rows on the arms, are large spherical granules, from one-fourth to one-half the size of the smaller tubercles, their bases also encircled by minute granules. In addition to these larger granules, there are many others, grading down to very minute ones which thickly cover the whole test.

Marginal plates are not conspicuous, in fact can be seen only as separated ossicles. Corresponding to the superomarginal plates are 3 ossicles (from interradial line), omitting the large plate at the extremity of the ray. The innermost ossicle is near the interradial line not far from its companion of the adjacent ray. The second plate is about 5 mm. from the first, and the third 8 mm. from the second. The third is 15 to 18 mm. from the large plate at tip. Each plate is convex, circular, about 3 mm. in diameter, and encircled by a row of regular, subquadrate, bead-like granules. Each plate bears 1 or 2 large spherical granules or small tubercles on its edge. The large plate at the end of the ray (7 mm. in length) is very convex, oval, and is surrounded by a regular series of small, bead-like granules.

Inferomarginal plates, 9 or 10 to each ray, are smaller than the superomarginals, and are separated from them by about 5 mm. of test, thickly covered with tubercles and granules. On the upper side of each ossicle is a large subconical tubercle, the series increasing in length toward tip of ray. Clustered about the base of each tubercle are numerous close-set granules of various shapes, which continue as a single row around the inferomarginal ossicle, and, at tip of ray, completely cover the exposed surface of distal 2 or 3 plates. The last are more tumid than the others, and are wedged in between the big terminal superomarginal and adambulacral plates. In addition, 2 or 3 pincer-shaped pedicellariae, with curved jaws, occur on the ventral side of the inferomarginal ossicles.

Actinal area is very knobby, with many spherical tubercles, much smaller than those of dorsal surface and more regularly arranged. Each plate bears 1 or 2 tubercles, surrounded by large, irregular granules, often subprismatic, 4-sided, or at least with a flattened side next to tubercle. An indefinite series of small granules often occurs outside of these, and near the furrow replaces them to some extent. Many actinal plates of ray have delicate pincer-shaped pedicellariae, with elongate jaws often curiously curved. They are smaller than those found on inferomarginals, and are present in interradial region.

Adambulacral armature similar to that of *elegans*. Composed as follows: (1) A nearly straight furrow series of 6 (often 5) spines, subequal except the adoral, which is smaller and hidden. Spines fit closely together, have blunt tips, and are flattened somewhat. They are united by a thin web for about half their length. (2) On first 6 to 9 plates 2 series of heavy blunt tubercular spines, the inner slightly longer than the furrow series. The inner series has 2 spines, the adoral the smaller. External to these stands the third spine, shorter than the inner, composing the outer series. On actinal surface of the other plates there are but 2 spines, standing in a transverse series; while near tip of ray only the inner spine persists, and is slender and pointed. Actinal spines are surrounded by a number of unequal irregular granules, 1 or 2 on the outer adoral corner being larger than others. No pedicellariae such as Sladen found in the *Challenger* specimen of *elegans* (*Challenger Asteroidea*, p. 353) are present on any of the adambulacral plates.

Mouth plates narrow, small, inconspicuous, with a furrow series of 11 spines like those of the adambulacrals except the inner 2, which are heavier, blunter, and form with the corresponding spines of the companion plate 4 teeth at each mouth angle. A row of 3 or 4 robust blunt spines are present on the actinal surface of the plate, parallel with the furrow series. A series of small pinched granules extends around the margin of each plate, except, of course, that part adjacent to the furrow.

Madreporic body small, convex, raised above general surface of integument. It is situated about one-third distance from center to margin, and lies off the exact interradial line. Striations convoluted. Anal opening eccentric, surrounded by large globular granules.

Color in alcohol, ashy.

Young: There appears to be no description of a young *Asterodiscus* beyond the few words of Gray. The young of the present species seems considerably different from that of *elegans*. Rays are well marked, regular, short, tapering from a broad base. Disk, large; interbranchial arcs widely angular.  $R=10$  mm.;  $r=6.5$  mm.  $R=1.54r$ . Marginal plates well developed, conspicuous, separated by an intercalated series of very much smaller ossicles, each bearing a globular granule nearly as large as the exposed surface of the plate. Superomarginals are 4 in number from median interradial line to extremity of ray, the last plate being very large and swollen as in the adult, and separated from that adjacent by a transverse series of 2 abactinal plates. Each plate with the exception of the last is slightly convex, is surrounded by a series of bead-like granules, and bears 2 or 3 granules on its surface, one being usually larger than the rest. The large plate has a smooth surface. It will be seen that superomarginals do not increase in number beyond this stage, the ray growing by the interpolation of abactinal plates between the superomarginals, principally between the third and fourth. Inferomarginals 8 from median interradial line, subcircular, surrounded by many small elongated granules in a definite series, each plate resembling a composite flower with short peripheral florets. A tubercle stands at the upper edge of each plate, and increases in size toward the end of ray. In the adult, which has but 10 inferomarginals, the growth of intermediate plates is principally between the third to seventh plates. The single intermediate series of plates between the dorsal and ventral marginals is readily distinguishable in the adult, and is situated rather nearer the inferomarginals, with which the intermediate plates alternate.

Abactinal plates are large, circular, arranged in very regular series parallel with the median radial row; or, in other words, they form chevrons, the axis of which is interradial. Plates decrease in size toward the periphery and each is surrounded by a circle of small bead-like granules and bears a large rounded, depressed tubercle which occupies the whole surface of the plate. Primary apical series very large, especially the "basals", which bear a much smaller convex granule in the center, instead of the enlarged tubercle. A single series of plates between adjacent basals. Within the apical area bounded by the basals are 5 regular plates (radial in position) and a definite "central". Primary "radials" are situated just outside of the basals; larger than others of the radial series. Papulae are distributed all over the abactinal surface. Madreporic body just outside of a "basal" plate.

Actinal intermediate plates are arranged in regular chevrons, and are not distinct superficially. Each is armed with a globular or obovoid tubercle surrounded by a semicircle of 2 to 5 pinched granules. Adambulacral plates have 3 spinelets in furrow series, and one actinal spine instead of 2 or 3. Several granules stand on the outer edge of the plate, one usually larger than the others. No pedicellariae are present.

The color of the young in life is cadmium orange; in alcohol bleached ashy or whitish.

Localities: Type (no. 21172, U. S. National Museum) from station 3940, vicinity of Laysan Island, 59-70 fathoms, white sand and broken shells; bottom temperature, 70°. Two young specimens from 4128, southeast of Kauai Island, probably about 68 fathoms, coarse brown coral sand, foraminifera.

#### Genus *CULCITA* Agassiz.

*Culcita* Agassiz, Mém. Soc. Sci. Nat. Neuchâtel, t. 1, 1835, p. 192.

#### *Culcita arenosa* Perrier.

*Culcita arenosa* Perrier, Recherches sur les Pedicellaires, 1869, p. 66; Révision des Stellérides, 1875, p. 264. Sladen, Challenger Asteroidea, 1888, p. 352.

*Culcita novaequinae* var. *arenosa*, Doederlein, Bericht ü. d. v. Herrn Prof. Semon bei Amboina ges. Asteroidea, in Semon, Zool. Forsch. in Australien u. d. Malay. Archipel. <Jenaische Denkschrift, bd. VIII, 1896, p. 315, taf. XIX, fig. 5 and 6.

This species was not taken by the *Albatross* expedition. The specimen which Perrier described was collected by the expedition of Eydoux and Souleyet in the *Bonite* in 1837, "des îles Sandwich."

## Family LINCKIIDÆ Perrier, 1875, emend.

*Linckiidæ* Perrier, Revision de la Collection de Stellérides du Museum d'Histoire Naturelle de Paris, 1875, p. 117.

Key to Hawaiian genera of *Linckiidæ*.

- a. Plates in regular longitudinal series, between which are regular series of papular areas. Adambulacral armature in 2 (rarely 3) unequal series, the outer heavier than the inner and more distinctly spaced.
- b. All the plates granular ..... OPHIDIASTER
- bb. Whole test covered with a thick membranous investment devoid of granules ..... LEIASTER
- aa. Abactinal plates not forming regular longitudinal series.
- b. Abactinal plates comparatively small. No papulæ on actinal surface. Papulæ in areas distributed among the abactinal plates. Adambulacral armature granuliform superficially, in 2 or 3 series ..... LINCKIA
- bb. Abactinal plates comparatively large. Papulæ in areas; sometimes present on the actinal surface. Adambulacral armature papilliform or spiniform superficially, usually in 3 series... NARDOA

## Genus OPHIDIASTER Agassiz.

*Ophidiaster* Agassiz, Prod. Monogr. d. Radiares. <Mém. Soc. Sci. Nat. Neuchâtel, t. 1, 1835, p. 191. Type, *Asterias ophidiana* Lamarck.

Key to Hawaiian species of *Ophidiaster*.

- a. Papular areas in 8 longitudinal series. Papulæ on actinal surface. One or 3 series of actinal intermediate plates.
- b. A single series of actinal intermediate plates.
- c. Well developed pedicellariæ present. Madreporic bodies 2, small ..... *lorioli* a
- cc. No pedicellariæ. A single moderately large madreporic body ..... *squameus*
- bb. Three series of actinal intermediate plates proximally, 2 distally. Actinal series of papular areas not reaching base of ray ..... *rhabdotus*
- aa. Papular areas in 6 longitudinal series. No papulæ on actinal surface. Two or 3 series of actinal intermediate plates.
- b. Abactinal and marginal plates neither nodose nor with conspicuous central naked area. Adambulacral spinelets in 2 series.
- c. Rays less than 4 times as long as diameter at base. Papular pores 9-15. Disk relatively large ..... *sclerodermus*
- cc. Rays more than 5 times as long as diameter at base. Papular pores 1 or 2. Disk small, rays slender ..... *tenellus*
- bb. Abactinal and marginal plates conspicuously tumid or nodose with naked central area. Adambulacral spinelets in 3 series ..... *triseriatus*

***Ophidiaster lorioli*, new species.**

Pl. xxxi, figs. 4, 4a-d; pl. xxxix, fig. 3.

Rays 5.  $R=31$  mm.;  $r=4.5$  mm.  $R=7r$ . Breadth of ray at base, 4.75 mm.; at middle of ray 4-5 mm. Height of ray at base, 4.5 mm.

Rays long, nearly cylindrical, or, in one case, distinctly depressed, tapering gradually on the outer part to a blunt extremity. Abactinal surface of disk slightly convex, a very slight constriction being present on dorsal surface between ray and disk. Papular areas regular, in 8 longitudinal series, 3 pores to the area except in the actinal series and on the outer third of ray, where there are usually 2. On disk there are but 7 or 8 areas, with 2 pores to each. The single series of actinal intermediate plates is not externally visible. The plates are much smaller than the inferomarginals, 3 or 4 of the former corresponding to 2 of the latter. The other plates of ray, namely, the radial, adradial, supero- and inferomarginals, form 7 longitudinal series, the plates being cordate, the narrower or adoral

<sup>a</sup>J. E. Ives has recorded (Proc. Philad. Acad. Sci., 1889, p. 172) 5 specimens of *Ophidiaster pusillus* Müller and Tröschel from Oahu. It is barely possible that these specimens are *O. lorioli*. *Ophidiaster pusillus* has pedicellariæ something like those of *lorioli*, but there are only 6 longitudinal series of papular areas. The species has been taken at Flores, Ar. boina, Philippine Islands, New Caledonia.

end overlapping the broader or aboral end of the preceding plate. The marginal plates are a trifle larger than the abactinal, and all are moderately convex, the transverse as well as the longitudinal furrows between the plates being well marked. The skin which covers the plates bears relatively large flat granules which are very much larger in the center of the plate than about the borders and smallest immediately surrounding the papulae. The small granules are very irregular in shape, and not at all uniform in size. The larger are more roundish and very slightly imbricating. In one specimen they imbricate more noticeably and appear remarkably scale-like, the outer or free edges being subangular or obtusely pointed in many cases. Extending along the papular furrow between the superomarginal and adradial series of plates on either side of the ray is a row of peculiar and conspicuous 2-jawed pedicellariae, about 10 to 12 in number, sometimes less. There is but 1 pedicellaria to an area and it is large enough to be readily seen without magnification. Each consists of a double, broadly spatulate, specialized depression with a denticulate margin, into which fit, when open, the broad fan-shaped jaws, which bear 5 teeth or serrations at the edge, fitting nicely into 5 notches in the edge of the specialized depression. The figure will give the exact appearance of these. There are also 3 to 5 of the pedicellariae scattered on disk (abactinal) and usually 1 in each actinal interradial area, although this is occasionally absent in 1 or 2 interradial. One or 2 pedicellariae may be found at base of ray adjacent to that in the interradius.

Adambulacral armature consists of 2 series of spinelets. Furrow series consists of small spinelets, the tips of which extend but a slight distance above the general granulation, and these tips are alternately larger and smaller although the difference is slight. When a portion of one side of the very narrow furrow is removed the spinelets are seen to be about twice as high as broad, with a rounded-truncate tip. The adoral is a shade narrower than the aboral member, but it is the latter that appears smaller (or more compressed) when viewed from the actinal surface. The difference in size is not constant, however, and is of little importance. Between 2 plates there is frequently a small granule fastened to the adoral edge of the adoral spinelet. On the actinal surface, spaced from the furrow spinelets a distance something less than their length, is a longitudinal series of larger ovoid tubercles which are not equidistantly placed, 3 to 6 of the furrow spinelets corresponding to 2 of the actinal. Small, rather scale-like granules are packed in the space between the 2 series of spinelets. The outer spinelets are bent away from the furrow.

Madreporic bodies 2, small, situated rather nearer the margin than midway to center of disk. They are situated in neighboring interradial, but one is somewhat off the median interradial line. The bodies are flush with the general surface and the striations are few and coarse, either a smaller sinuous line, or V-, U-, and Y-shaped. Anal apertures apparently 2, surrounded by larger granules.

Color in alcohol a bleached yellowish.

Locality, station 3834, south coast of Molokai Island, on reefs; shore (4 specimens). Type no. 21173, U. S. National Museum.

This species is closely related to *O. robillardi*<sup>a</sup> P. de Loriol, and more remotely to *O. germani*<sup>b</sup> Perrier and *O. cribrarius*<sup>c</sup> Lütken.

From *robillardi* it differs in having a coarser granulation, often scale-like, on the median portion of the plates, while that about the edges is finer; the pedicellariae are broader, with more denticulations, and the outer surface of each jaw is grooved near the free edge. The pedicellariae are single to a plate as in *robillardi*, but are situated in a papular area rather than on the plate. There is a slight inequality in the furrow spinelets, and the accessory granule, instead of being between the 2 spinelets of a plate as in *robillardi* is always found between 2 plates. The following synopsis will serve to indicate the chief differences between the 4 related species.

a. Papular pores 3 (2-4); plates more prominent.

b. Arms usually flattened, granulation uniform, pedicellariae narrower, 3 or 4 denticulations on free edge; outer surfaces of jaw not grooved; pedicellariae on plates; furrow spinelets equal; accessory granules between the 2 spinelets of a plate ..... *robillardi*

bb. Arms usually cylindrical, granulation conspicuously larger in center of plate; jaws of pedicellariae nearly or quite twice as broad as high; 5 denticulations on free edge; pedicellariae on edge of papular areas, one to an area; furrow spinelets rather unequal; accessory granules between the adjacent spinelets of 2 adjacent plates..... *lorioli*

<sup>a</sup>Catalogue Raisonné des Échinodermes recueillies par M. V. de Robillard à l'Île Maurice. <Mém. Soc. Physique et d'Hist. Nat. Genève, t. XXIX, no. 4, 1885, p. 24, pl. xv, figs. 1-5.

<sup>b</sup>Révision des Stellérides, 1875, p. 130.

<sup>c</sup>Vidensk. Meddel., 1871, p. 277.

aa. Papular pores 10-12; plates less prominent.

b. Furrow spinelets equal.....*germani*

bb. Furrow spinelets unequal.....*cribrarius*

*Ophidiaster robillardi* is found at Mauritius, an interesting fact when considered in connection with *Valvaster striatus*, a species from Mauritius also occurring in the Hawaiian Islands. *Germani* is found at New Caledonia and *O. cribrarius* at the Tonga Islands and Samoa.

Named in honor of Prof. P. de Loriol, author of a classical series of papers on living and fossil echinoderms.

***Ophidiaster squameus*, new species.**

Pl. xxxi, fig. 6, 6a-b; pl. xxxvii, fig. 4.

Rays 5. R=19 mm.; r=3 mm. R=6.3r. Breadth of ray at base, 3.25-3.75 mm.; at middle of ray 3.75 mm.

Rays unequal, cylindrical, scarcely tapering at all until the outer third is reached, and then only slightly. Tip blunt; terminal plate large, conspicuous, smooth, several small tubercles being present at the outer end. No pedicellariæ whatever. Papular pores in 8 longitudinal series, 2 or 3 conspicuous pores to each area, but only one at the tip of ray and on disk. The plates are markedly convex, and the longitudinal series are very regular and separated by very evident papular furrows which extend the length of the ray. In a transverse direction the plates are marked off by a trifle shallower furrows, at the bottom of each of which is a narrow groove bordered by fairly regular globular granules. The plates are cordate and arranged in a radial series on either side of which is an adradial, supero- and inferomarginal, and an actinal intermediate series bordering the adambulacrals. There are 2 actinal intermediate plates to each inferomarginal. The plates are covered with relatively very coarse granules for the genus, and these are subcircular to oval, convex, and much larger in the convex central portion of the plate than at its edges. Along the aboral and adoral edges they frequently form a border to a narrow groove as already indicated. From 2 to 6 or 7 granules in the center, especially on the marginal plates, are conspicuously larger than the others and imbricate slightly, but slight spaces are frequently seen where the circular granules touch and do not overlap. On the inferomarginal plates 1 or 2 of the granules, especially on the outer part of the ray, are subcircular.

Furrow spinelets are not so large, 2 to the plate, equal, slightly over twice as long as wide, round-tipped and flattened. As they are placed on the plate the adoral appears outwardly a trifle longer than the other. Each spinelet has a small elliptical granule fastened to the furrow side and lying over the crack between adjacent spinelets. The lower end of this granule reaches about to the middle of the spinelet, and its upper end falls considerably short of the tip. Spaced from the furrow series, on the actinal surface, is a longitudinal row of much stouter, broadly ovoid or subconical granules or tubercles, of which 2 correspond to 3 furrow spinelets. The space between the 2 series is filled in with small, compressed subsquamiform granules, about 1 series of which pass between the actinal spinelets. The actinal intermediate plates have 1 or 2 central granules larger than the rest, but the general granulation of these plates is intermediate between that of the adambulacrals and the inferomarginals.

Madrepore body fairly large, regularly circular, situated about midway between center and edge. About the edge of the plate, which is perfectly flat, is a smooth unstriated border. Striations coarse, irregular. On the adcentral side are 5 or 6 granules larger than the others. Anal opening guarded by 4 triangular granules much larger than any others nearby.

Color in life, vermilion; in alcohol, pinkish with pale yellowish spots here and there.

Localities: Station 4100, Pailolo Channel, between Maui and Molokai islands, 130-151 fathoms, coral sand, shells, foraminifera; bottom temperature 61°; 1 specimen. 4023, Vicinity of Kauai Island 18-41 fathoms, gray sand foraminifera, coral, rocks; 1 specimen, very young. Type no. 21174, U. S. National Museum.

The nearest related species to this appears to be *Ophidiaster purpureus* Perrier<sup>a</sup> from which *squameus* differs in having a still coarser granulation, in being devoid of pedicellariæ, and in having thicker actinal adambulacrals spinelets, which are also situated closer together, so that 1, or at most 2, series of small granules separate them. The terminal plate is apparently larger than in *purpureus*, and the arms relatively shorter. It differs in the same respects, practically, from *O. pustulatus* (v.

<sup>a</sup> Recherches sur les Pedicellaires, etc., 1869, p. 61. Révision des Stellérides, 1875, p. 127.

Martens)<sup>a</sup> with which Doederlein<sup>b</sup> has recently united *purpureus*, the 2 having been taken at Mauritius; and the former is recorded also from Amboina and Flores, and the latter from the Seychelles. The name refers to the large granules which have the appearance of scales.

***Ophidiaster triseriatus*, new species.**

Pl. xxx, fig. 3; pl. xxxi, figs. 7, 7a.

Rays 5. R=18.5 mm.; r=4 mm. R=4.6 r. Breadth of ray at base, 4.75—5 mm.; ray about 5.2 times as long, measured on side, as width at base.

Disk rather large for genus, rays stout; slightly tapering to a blunt extremity which is capped by a tumid terminal plate bearing 3 or 4 low tubercular knobs. Rays well arched above, slightly flattened actinally, yet rounded. Interbranchial arcs acute, fairly wide. Abactinal and marginal plates very tumid, forming 7 fairly regular series separated by conspicuous furrows containing papular areas. Medioradial and superomarginal plates largest and most convex, some of them appearing almost hemispherical. Proximal plate of each radial series largest of all, forming a regular pentagon on disk. Between inferomarginals (which are smaller than superomarginals) and the adambulacrals are 2 rows of actinal intermediate plates proximally, becoming 1 on distal two-thirds of ray. The granulation is of medium coarseness. Granules are roundish or roundish polygonal, and are a trifle larger in the center of those plates which are wholly covered than in the papular furrows. Transverse, fairly regular, fine cracks between larger plates are bordered by slightly enlarged granules. The cracks are usually conspicuous between marginal plates, and on proximal portion of ray. Most of the plates of median radial series (including the large primary radial) and of superomarginal have the exposed rounded surface either partially or wholly free from granules. A number of the adradial and inferomarginal plates, which are not so tumid as the others, have a naked central area. This exposed portion of the plate is quite smooth and on the distal half of the ray is rather more hemispherical and prominent than elsewhere (excepting the 5 primary radials). A number of adradial and superomarginal plates possess a 2-jawed spatulate narrow pedicellaria with curved spectacle-shaped (pince-nez) fosse very similar to those of *O. sclerodermus*. The fossæ are surrounded by a small naked area. Papular areas in 6 longitudinal rows, 3 to 5 small pores to each area. On distal portion of ray, owing to the crowding of the adradial series of plates by enlarged radial and superomarginal plates, the adradial series of papulæ is absent and the superomarginal is reduced to a single pore to an area, or, at very tip, where the superomarginal and radial plates touch, both series of papulæ may be wanting. Inside apical area of disk there is but 1 pore to a papular area.

Adambulacral furrow spinelets 2 to each plate, oblong, equal, round-tipped to truncate. Separated from these by a distance equal to one-half to three-fourths their length is a flat obovate squamiform spinelet or tubercle, on actinal surface of plate. These form a very regular series and are directed away from furrow. Touching the base of each of these spines on the aboral side is a round-tipped slightly compressed granule, larger than the other granules of actinal surface, the series of which is quite regular and is intermediate between furrow and actinal spines. Granulation of actinal surface is very slightly coarser than that of abactinal, but surrounding the adambulacral spines is a trifle finer than on actinal intermediate plates. On one ray there is a single pedicellaria on 1 of inner plates of latter series.

Madreporic body subcircular, situated between 2 large convex radial plates. Striations irregular, branching, centrifugal. Six or 7 enlarged granules surround subcentral anal aperture.

Variations: Another much smaller specimen from the same station (R=7 mm.) agrees very well with the type except that the plates, especially the primary radials, are not so prominent, and all of the latter but one are covered with granules. The intermediate series of adambulacral granules is much more prominent than in the type, nearly or quite equaling the furrow granules or spinelets in size. As would be expected, papulæ are fewer, there being but 1 to each area. Pedicellariæ are as yet undeveloped. Many of the plates of ray, as in the type, are naked, but this portion is not quite so prominent, although already very convex.

Locality: Station 4128, vicinity of Kauai Island, 68-90 fathoms, coarse brown coral sand, foraminifera, 2 specimens. Type no. 21176, U. S. National Museum.

<sup>a</sup> Ostasiat. Echinod. <Arch. f. Naturg., Bd. 32, 1866, p. 62.

<sup>b</sup> Bericht. ü. d. v. Herrn Prof. Semon bei Amboina ges. Asteroidea, in Semon, Zool. Forsch. in Australien u. d. Malay Archipel. <Jenaische Denkschrift, Bd. VIII, 1896, p. 317.

This species is characterized especially by the very prominent abactinal plates, many of which are naked centrally and form well-rounded bosses along the rays; also by the form of the pedicellariæ and the character of the adambulacral armature, which is disposed in 3 series, the median being smaller than either the outer or inner. In the latter feature this species bears a certain resemblance to *O. tuberifer* Sladen, but is otherwise quite different, as may be seen by comparing figures. Although the type is still probably young, the characters appear to be sufficiently well marked to merit description. The name refers to the 3 series of adambulacral granules.

***Ophidiaster sclerodermus*, new species.**

Pl. xxx, figs. 4, 4a; pl. xxxi, figs. 2, 2a.

Rays 5. R=63 mm.; r= 13 mm. R=4.8 r. Breadth of ray at base, 15-16 mm.; at middle of ray, 10 mm. Height of ray at base, 10 mm.

Disk decidedly large for genus; rays only moderately long, tapering from a fairly broad base (for the genus) very gradually to a blunt extremity, which is tipped by a prominent terminal plate. The rays are decidedly broader at base than elsewhere, and measured along its side each ray is  $3\frac{1}{2}$  times longer than broad. The interbranchial angles, about  $75^{\circ}$  to  $85^{\circ}$ , are not sharp. Abactinal surface convex, but only slightly so in middle of disk; actinal surface nearly plane, the inferomarginal plates forming a well-rounded border to the area. No papulæ on ventral surface.

The plates are prominent on abactinal and lateral surfaces, the longitudinal series being separated by prominent but shallow papular furrows. The transverse divisions between the plates are not nearly so evident, the plates themselves being entirely hidden by the finely granular, thick skin. One can distinguish readily a radial series, and on either side an adradial, a supero, and inferomarginal, the superomarginal defining border of ray when viewed from above. Between the inferomarginal and adambulacral series there are, at base of ray, 3 series of smaller intermediate plates, which are reduced to 2 beyond the proximal third of ray and to 1 on distal third. There are no papular pores between these plates. Whole body is covered with a remarkably tough, thick skin, which is closely covered with a uniform, very fine granulation. Although this specimen is many times larger than the type of *O. lorioli*, the granules are actually much smaller. On the outer third of the ray the plates are frequently irregular in disposition, and on 1 ray of the type the plates are all irregular, as if from some sort of injury. Papular areas form 6 longitudinal series; 9 to 14 pores to an area on proximal two-thirds of ray, but on the distal portion fewer; and frequently there many papular areas are absent. The pores are many times larger than the granules, which are here a trifle larger than on the plates. The pores form irregular stenciled lines, resembling letters or simple hieroglyphics. There are few papular areas in the central portion of disk. Small 2-jawed entrenched pedicellariæ are abundant. Each consists of 2 narrow, spatulate, smooth blades, set in a little pit and lying each in a specialized depression with a smooth, rounded border. The whole apparatus is 1.5 mm. long, and the jaws are usually curved, making it crescent-shaped. On the proximal part of ray a series of 3 to 12 of these pedicellariæ are present just external to the outer adambulacral spinelets, and they are widely scattered on the marginal and abactinal plates, 1 to a plate, but are most numerous in the proximal regions. Occasionally a pedicellaria has 3 jaws.

Furrow spinelets, 2 to a plate, are much flattened, rounded-truncate, subequal, or the adoral is a shade narrower at the base. They are about twice as long as broad and the adoral is usually a little broader at the tip than at the base. The furrow face is flat or a trifle concave near base. External to these spinelets, at a distance equal to one-third or one-half their length, is a regular series of equidistant, somewhat flattened, broadly ovoid tubercles, the exposed portion of which is about two thirds the length of the furrow spinelets, of which about 3 correspond to 2 tubercles. Packed closely about the tubercles and filling the space between them and the furrow are many roundish or compressed granules, a trifle larger than the rest of actinal granules. Here and there one can distinguish lines, bordered by slightly larger bead-like granules, running out from the furrow toward the marginal plates, and similar fainter lines can be distinguished, with the aid of a glass, between many of the plates themselves. The mouth spinelets are like the adambulacral but a trifle larger.

Madreporic body inconspicuous, but fairly large, cordiform or shield-shaped. Striations fine, interrupted, branching, centrifugal. The plate is perfectly flat and is situated nearer margin than center. Anal aperture is surrounded by a number of considerably enlarged granules.

Color in life: Above, orange yellow with maroon blotches; below, light yellow. In alcohol, bleached grayish yellow or ashy.

Locality: Station 4077, north coast of Maui Island, 99-106 fathoms, fine coral sand, foraminifera, bottom temperature 70°; 2 specimens. Type no. 21175, U. S. National Museum.

***Ophidiaster tenellus*, new species.**

Pl. xxxi, figs. 5, 5a.

Rays 5.  $R=52$  mm.;  $r=7.5$  mm.  $R=7$  r. Breadth of ray at base, 9 mm.; at middle of ray, 5 to 5.5 mm. Height of ray at base, 6 mm. Rays  $5\frac{1}{2}$  times as long as diameter at base measured along side.

In general features resembling the preceding species, but with much longer and slenderer rays, a relatively coarser but uniform granulation, a very much thinner skin, 1 or 2 pores to each papular area, and fewer pedicellariæ. The third or outer series of actinal intermediate plates is rudimentary.

The plates are a trifle less prominent than in preceding species, but there is a perfectly evident though extremely fine transverse crack traversing the granulation between the plates. The longitudinal papular furrows are well marked but shallow. There are 6 rows of papulæ, which are solitary or in twos (rarely 3). No papulæ on actinal surface. The granulation is fine and uniform but increases in coarseness on the actinal surface near the furrow, where the granules occasionally appear scale-like. As in the last species the plates on one ray are somewhat irregular in disposition near the extremity. Two- or occasionally 3-jawed pedicellariæ form a series on the proximal third of ray at either side of the furrow just external to the outer adambulacral spinelets, and a similar series is present on the outer row of actinal intermediate plates and fewer on the 2 series of marginals. On abactinal surface pedicellariæ are rare.

The furrow spinelets are about equal in size, 2 to a plate, and slightly spaced. They are much flattened, truncate, a trifle broader at the tip than base, and the inner or furrow face has a very shallow groove running from end to end. The spinelets project a considerable portion of their length beyond the general level of the actinal surface of the plates. The actinal adambulacral tubercles are flattened, ovoid or obovoid, granuliform, bent away from furrow, and form a series just external to the furrow spinelets, so that only 1 series of granules intervenes between the 2. There is 1 of these tubercles to every third or fourth furrow spinelet, and they are not nearly so long as the latter. The granules of the adambulacral plates are larger than those of the actinal intermediate plates, into which they grade imperceptibly.

Madreporic body circular, of moderate size, situated midway between center and interbrachial angle. Striations deep, irregular, branching, centrifugal.

Color in life: Buff above, deeper ochraceous in the papular areas; below, cream color. In alcohol, ashy.

Locality: Station 4100, Pailolo Channel, between Molokai and Maui Islands, 130-151 fathoms, coral sand, shells, foraminifera; bottom temperature 61°. 1 specimen, type no. 21177, U. S. National Museum.

***Ophidiaster rhabdotus*, new species.**

Pl. xxx, fig. 2; pl. xxxi, fig. 8.

Rays 5.  $R=80$  mm.;  $r=11$  mm.  $R=7.3$  r. Breadth of ray at base, 11 mm.; at middle of ray, 8.5 mm. Height of ray at base, 8 mm. Ray 5 to 6 times as long as diameter at base, measured along side. Interbrachial arcs not very acute. Rays appear conspicuously fluted.

In general form resembling the preceding species, but differing in having more regular and more convex abactinal and marginal plates, 8 instead of 6 rows of papular areas, and 4 pores (3 to 5) instead of 1 to the area; outer or third row of actinal intermediate plates reaching one-third length of ray, and granulation a trifle coarser.

Marginal and abactinal plates form 7 regular convex series separated by 6 equally regular furrows containing the papular areas. At tip of some of the rays this regularity is completely interrupted. There is also a slight transverse furrow between consecutive plates, but this is not nearly so conspicuous as the longitudinal sulcus. In the granulation between consecutive plates there is likewise a fine transverse crack, which is sometimes bordered by slightly larger granules. The marginal plates are slightly larger than the abactinal, and very regular except at end of ray. Between the inferomarginal

and adambulacral plates are 3 series of regular actinal intermediate plates, but beyond the twelfth inferomarginal or basal third of ray there are but 2 such. There are 8 rows of papular areas, the actinal row (between inferomarginal and outer actinal intermediate plates) ending within 10 to 15 mm. of the interbrachial arc. This series contains but 2 or 3 pores to the area, and is not sunken in a furrow, as the marginal and dorsal areas, which comprise 4 or 5 pores, usually 4. The plates are covered, as in the 2 preceding species, with a membrane closely beset with fine granules. This skin is thinner than in *sclerodermus* and the granules are relatively considerably larger, yet fine, being coarsest on the convexity of the plates and only one-fourth or one-third as coarse in the bottom of the papular furrows. The granulation becomes very gradually coarser on actinal intermediate plates, yet is relatively (to the size of the spinelets) finer immediately adjacent to furrow than in *tenellus*, since the granules again grow smaller as they surround the actinal furrow spinelets. Here and there on the abactinal plates, and on the papular areas of intramarginal series, as well as on the actinal intermediate plates of proximal portion of ray, are small "spectacle-shaped" pedicellariae, occurring singly, similar to but smaller than those of *sclerodermus*. The figures will sufficiently show the form. On proximal portion of the ray a short series of them occurs just exterior to the actinal furrow spinelets. The jaws rest in similarly shaped specialized fossæ, as in the 2 preceding species.

The furrow spinelets are similar to those of the 2 preceding species. There are 2 to a plate, and the tip is rounded or subtruncate, projecting well above the general surface. The actinal adambulacral spinelets are also flattened and obovate in outline, bent away from the furrow. They very nearly, or quite, touch the furrow spinelets, only 1 series, if any, of fine granules intervening. (Compare figure with *sclerodermus*.) These actinal spinelets are relatively larger than in either of the 2 preceding forms and lie closer together, only 1 or at most 3 series of very fine granules separating them. As noted above, the adambulacral granules are smaller than those of the actinal intermediate plates, while in the 2 preceding species the reverse is the case.

Madreporic body subcordiform or shield-shaped. Striations centrifugal, but very irregular and interrupted. The plate is perfectly flat, and is situated nearer the margin than the center. Anal aperture is surrounded by a number of much enlarged granules.

Color in alcohol, dull dark brown; in life unknown; evidently darker than either of the preceding forms.

Locality: Station 3982, vicinity of Kauai Island, 233-40 fathoms, coarse brown coral sand, shells; bottom temperature, 48.5°; 1 specimen, type no. 21178, U. S. National Museum.

This is a more typical *Ophidiaster* than either of the 2 preceding species, on account of the 8 rows of papular pores. The submarginal series of either side is ventrolateral rather than actinal. But this form nevertheless has 3 rows of actinal intermediate plates, and the actinal surface is rather flat, not arched, as in *lorioli*. The name refers to the fluted character of the rays.

#### Genus *LEIASTER* Peters.

*Leiaster* (subgen.) Peters, Monatsber. d. k. preuss. Akad. d. Wiss. Berlin, April, 1852, p. 177.

#### *Leiaster callipeplus*, new species.

Pl. xxx, figs. 1, la; pl. xxxi, fig. 3.

Rays 5. R=52 mm.; r=8 mm.; R=6.5 to 6 r. Rays not all equal; shortest 47 mm. Breadth of ray at base, 8 mm.; at widest part of ray, 9 mm.

Rays subcylindrical, slightly constricted at base; of a nearly uniform caliber throughout; slightly broader than high, abruptly tapering to a blunt point. Rays fairly short for genus. Abactinal surface of disk slightly convex; interbrachial angle acutely rounded. No pedicellariae of any description.

The whole test is covered by a thick, tough, smooth skin, which in the living state very effectively hides the plates, but in a dried state shrinks and allows the plates to be clearly seen. The papular areas, which are large, form 8 longitudinal series along the arms, but are irregularly scattered and much smaller on disk. Of these 8 series 1 is situated on either side of the ambulacral furrow, another on either side between the 2 marginal rows of plates, while the remaining 4 are on the convex abactinal surface. The actinal areas have 6 to 10 papular pores, the abactinal about 15, and all the pores are very small in alcoholic specimens. In many of the papular areas of dried specimens what appear to be 2 or 3 granules can be seen imbedded in the integument. The skeleton is composed of longitudinal,

usually regular, series of 4-sided plates with rounded corners and slightly excavated sides. These small plates imbricate in the longitudinal direction, and each is joined to its neighbor of the adjacent series by a transverse, much smaller ossicle, the series being separated from each other by about one-half the width of a plate. There are 7 rows of these larger plates; namely, a radial, an adradial, a superomarginal, and an inferomarginal. Adjacent to adambulacral plates is a row of small plates, of which 2 correspond to each inferomarginal plate, to which every pair of intermediate plates is joined by the usual transverse ossicle. The papular areas between the actinal and inferomarginal plates are smaller than the others. (Pl. xxx, fig. 1a.)

Adambulacral plates are much smaller than the actinal plates, and are set obliquely as regards their dorsoventral direction, the outer end of the proximal plate underlying the adoral end of the succeeding plate. The actinal surface of each plate is wider than long, and between the plates are conspicuous sutures, all being hidden by the thick skin. Armature consists of a furrow series of 3 short, equal, spinelets, flattened and with rounded tips. The spinelets stand nearly parallel, and are invested by a continuous membrane extending from the inner mouth spines to tip of ray. The edge of this membrane or skin is serrated by the tips of the spinelets. Surface of spinelets is plane, not grooved, on the inner side. On actinal surface of about every other plate is an upright, robust, slightly compressed spinelet about 1 mm. in length. It is invested, also, in membrane, except the rounded roughened tip. On actinal surface of mouth plates these spinelets are slightly larger (1.5 mm.).

Terminal plate of arm tubercular, armed with 3 or 4 minute granules or spinelets. Madreporic body circular, perfectly plane, situated rather nearer margin than midway between it and center of disk; marked by fine radiating striations. Anal aperture very inconspicuous except in dried specimens. It is surrounded by a number of minute spinelets, wholly obscured by the integument in alcoholic specimens.

Color in life: Abactinal surface and sides a deep maroon purple, with a decided magenta tint at the ends of arms. The purple tends somewhat to pansy purple, but is hardly so blue. Actinal surface maroon purple, the series of actinal adambulacral spinelets phlox purple. Tube feet deep cadmium yellow. In alcohol all the color is lost, and the specimen becomes a dirty faded yellow.

Localities: Type (no. 21179, U. S. National Museum) from station 4149, vicinity of Bird Island, 33-71 fathoms, coral and coralline; bottom temperature 77.7° (surface temperature 78°). Taken also at the following stations, in all, 8 specimens:

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
3872.....	Auau Channel, between Maui and Lanai islands.....	<i>Fathoms.</i> 43-32	Yellow sand, pebbles, coral.
3875.....	do.....	65-34	Fine gray sand.
4128.....	Vicinity of Kauai Island.....	About 68	Course brown coral sand, foraminifera.
4164.....	Vicinity of Bird Island.....	40-56	Coral sand, pebbles, shells.

This strikingly colored starfish is a shallow-water form. The genus contains 5 other species: *L. coriaceus* (Peters), Querimba Island, Mauritius; *L. glaber* (Peters), Querimba Island; *L. leachi* (Gray), Mauritius; *L. speciosus* von Martens, off Flores and Fiji islands; *L. teres* (Verrill), La Paz, Lower California. The present species is apparently nearest *L. glaber* from Querimba Island, but the original description of Peters is too incomplete to lend much aid in determining the specific differences.

**Genus LINCKIA Nardo.**

*Linckia* Nardo, De Asteriis, Oken's Isis, 1834, p. 717. Type, *Linckia typus* Nardo = *Linckia levigata* (Gmelin) 1788. *Cribrella* Agassiz, Mem. Soc. Sci. Nat. Neuchâtel, t. 1, 1835, p. 191.

*Key to Hawaiian species of Linckia.*

- a. Spinelets bordering ambulacral furrow alternately larger and smaller. Occasionally a third aboral granule is present in these adambulacral series; 2 madreporic bodies..... *diplax*  
 aa. Spinelets bordering ambulacral furrow about equal, but separated by a perpendicular series of 4 or 5 granules; 2 madreporic bodies..... *multifora*

*Linckia diplax* (Müller and Troschel).

Pl. XXIX, fig. 4; pl. XXXI, fig. 7.

*Ophidiaster diplax* Müller and Troschel, System der Asteriden, 1842, p. 40.*Linckia diplax*, Lütken, Videnskabelige Meddelelser, 1871, p. 268.*Linckia pacifica* var. *diplex*, Sladen, Challenger Asteroidea, 1889, p. 410.

A large specimen of this species was taken at station 3848, off the south coast of Molokai, to which may be added a small specimen from 3872, although the identity of the latter is not so certain. The large example has 4 arms and 2 madreporic bodies, and its dimensions are as follows: R=138-140 mm.; r=10-11.5 mm.; R=12-14 r. Breadth of ray at base about 14 to 15 mm.; at widest part, in middle, 17.5 mm. Ray about 9 times as long as breadth at base measured along one side of ray. Rays are considerably flattened in the central portion, narrower at the base and gradually tapering to a blunt extremity which is slightly upturned. Papular areas numerous, rather larger than individual plates but smaller on the disk. Pores 15 to 25, small. On the lateral face of the arm 3 more or less distinct regular longitudinal rows of plates can be distinguished. Between the lowermost of these series and the adambulacral plates are 3 longitudinal series of actinal intermediate plates, those of the innermost series largest. Granules of the abactinal area very fine, much larger on the convexity of the plate than in vicinity of papular pores. On the ventral surface the granules are much larger, polygonal, and increase in size toward the furrow. The adambulacral armature is in 2 regular contiguous series. The inner series is composed of rather flat, broad, usually spatulate spinelets, with heavy rounded tips, separated by a much narrower spinelet about two-thirds the length of the larger. The smaller alternates more or less regularly with the large spinelet. There may be also a third spinelet, very small, almost a granule, in fact, on the aboral end of the plate. This is not common, however. Frequently the "smaller" spinelet nearly equals the larger in length but is always narrower and not spatulate. The spinelets of the external series are contiguous with those of the inner and are less numerous, there being 1 to about every 2 of the furrow spinelets. They are slightly larger than the latter, are not greatly flattened, and their tips are thick and rounded. Outside of these there are indications of a third rather irregular series which may be easily confused with the general granulation of the actinal surface, except that the latter is polygonal, while the larger granules are more rounded. Though polygonal at times, they rise slightly above the general surface.

In the small specimen 3 of the 5 arms are regenerating and the second madreporic plate is almost rudimentary. R=33 mm.; r=4 mm.; R=8 r. Breadth of ray at base 4.5 mm. The arms are more cylindrical than in the large specimen. Papular areas are much smaller than the surrounding plates; pores about 6 to each area. The 3 lateral longitudinal series of plates are distinct. Adambulacral armature is as in the large specimen, but the outer or third series is quite distinct. The granulation is relatively coarser than in the larger example, and less crowded, especially on the actinal surface, so that the granules are globose rather than polygonal. In size this specimen is more nearly like *Linckia ehrenbergi* (Müller and Troschel), to which the papular areas, smaller than the plates, also would refer it, but it is probably to be looked upon simply as a young *diplex*.

The species which is nearest to *L. diplax* is *L. pacifica*, which differs in having but one madreporic body. *L. ehrenbergi* is also very similar, but the arms are shorter (R=7.5 r); also the spinelets of the actinal adambulacral series are said by P. de Loriol (Mém. Soc. Phys. et d'Hist. Nat. Genève, t. xxix, 1885, p. 34) to be slightly larger than those of the furrow and equal in *diplex*. But in the Hawaiian specimen, which is out of proportion for *ehrenbergi*, the actinal spinelets or granules are slightly larger, or at least the exposed tip heavier, so that this character is hardly to be relied upon. *Linckia multifora* differs in the disposition of the adambulacral furrow spinelets, which are separated by a perpendicular series of 4 or 5 granules. The actinal spinelets are not contiguous with the furrow series, and are of about the same size as the latter. The general appearance of the 2 forms is very similar.

Perrier (Rév. Stell., p. 145) notes that *diplex* occasionally has 3 madreporic bodies.

Localities: Station 3848, south coast of Molokai Island, 44 to 73 fathoms, sand and gravel; 3872, Auau Channel, between Maui and Lanai islands, 43 to 32 fathoms, yellow sand, pebbles, coral.

*Linckia multifora* (Lamarck).*Asterias multifora* Lamarck, Animaux sans vertèbres, t. II, 1816, p. 565.† *Linckia typus* Gray, Ann. N. H., ser. I, vol. v, 1840, p. 284.† *Linckia leachii* Gray, ibid., p. 285.*Ophidiaster multiforis*, Müller and Troschel, System der Asteriden, 1842, p. 31.*Linckia multiforus*, Gray, Synop. of the Species of Starfishes, 1866, p. 14. (Also *L. typus* and *L. leachii*.)

*Linckia multiformis*, von Martens, Ueber Ostasiat. Echinod. <Archiv. für Naturgesch., jahrg. XXXII, 1866, bd. 1, p. 65.

*Ophidiaster multiformis*, Edm. Perrier, Pédicellaires, 1869, p. 59.

*Linckia multiforma*, Lütken, Videnskabelige Meddelelser, 1871, p. 267, and authors generally since then.

This species is recorded from the Sandwich Islands by Perrier (Révision des Stellérides, p. 150). No specimens were taken by the Hawaiian expedition.

It is not unlikely that with further search in shallow water other forms of *Linckia* may be brought to light. The genus is a rather difficult one. Most of the species look very much alike, so that it is not easy adequately to characterize them without the use of figures. Three well-known forms have not yet been figured (or at least not where the average student can find them). Since other species may subsequently be found in the Hawaiian Islands, I have ventured to compile from descriptions the following synoptical table of the common species of the genus. *Linckia multiforma*, *ehrenbergi*, and *marmorata* are figured in P. de Loriol's "Catalogue Raisonné des Echinodermes de l'Isle de Maurice" (Mém. Soc. Phys. et d'Hist. Nat. Genève, t. xxix, 1885), and *L. guildingi* (*L. ornithopus* of Müller and Troschel), an Atlantic form, in Agassiz's "North American Starfishes" (Mem. Mus. Comp. Zool., vol. v, no. 1, 1877).

*Key to the commoner Pacific species of Linckia.*

- a. Furrow spinelets separated by several granules in a perpendicular series.
- b.  $R=10-12$  r. Arms 9 times as long as wide. Papular areas numerous, small, about the size of the plates, 6 to 12 pores. There is no median radial area free from papular areas. Two or 3 madreporic bodies. .... *multiforma*  
(Red Sea, Mozambique, Mauritius, Ceylon, Larentuka, Celebes, Amboina, New Caledonia, Fiji, Samoa, and Hawaiian Islands.)
- bb.  $R=6$  r. Rays 5 times as long as wide. Papular areas rather large, superficially larger than the plates. There is a median radial area free of papular areas. One madreporic body.  
*laxigata* (*L. miliaris*)  
(Red Sea, Mozambique, Mauritius, Zanzibar, Ceylon, Madras, Andaman Islands, Flores, Timor, Celebes, Batjan, Philippines, N. Australia, Claremont Island, New Caledonia, Caroline, Fiji, and Samoan islands.)
- aa. Furrow spinelets not separated by several granules in a perpendicular series.
- b. Only 1 madreporic body.
- c. Two series of adambulacral spinelets contiguous.
- d.  $R=8.3$  r. Abactinal plates in 3 irregular series. A certain number of these plates, more prominent and generally rounded, form bosses or "nodosities" irregularly disposed. Papular areas small, with 8 pores, sunken. Furrow spinelets alternately large and small; the small are cylindrical, the larger broader at tip. The external series is composed of granules or spinelets contiguous with the furrow series, each situated opposite a smaller spinelet. They are slightly larger than the larger furrow spinelets. A third series is also present, larger than the other actinal granules and separated from the external adambulacral spinelets by a space covered with smaller granules. .... *nodosa*  
(Tortugas, Arafura Sea, Torres Strait, *vide* Bell.)
- dd.  $R=10.6-12.5$  r. Abactinal plates numerous and irregular, equal, not especially prominent, about the same dimensions as the papular areas. Adambulacral spinelets in 2 contiguous series, the inner consisting of alternately large and small spinelets. Those of external series are equal; slightly larger and less numerous than the inner series.  
*pacifica*  
(Mauritius, Nicobar Islands, Andaman Islands, Tahiti, Samoan Islands.)
- cc. The 2 series of adambulacral spinelets separated by a granular area. .... *marmorata*  
(Mauritius, Prince of Wales Channel, Port Molle, Fitzroy Island.)
- bb. Two or occasionally 3 madreporic bodies.
- c.  $R=13$  r. Length of ray=12 times width. .... *diplax*  
(Mauritius, Madagascar, Isle of Bourbon, Christmas Island, New Caledonia, Fiji, and Tonga islands, Hawaiian Islands.)
- cc.  $R=7.5$  r. Length of ray=7 times width. .... *ehrenbergi*  
(Red Sea, Mozambique, Mauritius.)

**Genus NARDOA Gray.**

*Linckia* (pars) Müller and Troschel, Monatsber. d. k. preuss. Akad. d. Wiss., Berlin, 1840, April, p. 103.

*Nardoa* Gray, Ann. N. H., ser. 1, vol. v, Dec., 1840, p. 286.

*Gomophia* Gray, *ibid.*

*Scyrtaster* (pars) Müller and Troschel, System der Asteriden, 1842, p. 34. Lütken, Videnskabelige Meddelelser, 1864, p. 163.

Perrier, Révision des Stellérides, 1875, p. 156.

*Ophidiaster* (pars) Müller and Troschel, System der Asteriden, 1842, p. 28.

*Nardoa* Sladen, Challenger Asteroidea, 1889, p. 411. Type *Asterias variolata* Retzius (the *Asterias variolata* of Lamarck, and *Linckia variolata* of Nardo and of Agassiz).

***Nardoa ægyptiaca* (Gray).**

*Gomophia ægyptiaca* Gray, Ann. N. H., ser. 1, vol. vi, 1840, p. 286.

*Scyrtaster ægyptiacus* Perrier, Révision des Stellérides, 1875, p. 164.

*Nardoa ægyptiaca* Sladen, Challenger Asteroidea, 1889, p. 788.

Recorded by Sladen (l. c.), from the Sandwich Islands. I have been unable to find the original record. This species was not taken by the *Albatross* expedition.

**Family GYMNASTERIIDÆ Perrier, 1884, emended.**

Gymnasteriidæ Perrier, Mémoire sur les Étoiles de Mer, etc. <Nouv. Archives Mus. Hist. Nat., t. vi, 1884, p. 165.

**Genus GYMNASTERIA Gray.**

*Gymnasteria* Gray, Ann. N. H., ser. 1, vol. vi, 1840, p. 278. Type, *Asterias carinifera* Lamarck.

*Asteropsis* (pars) Müller and Troschel, System der Asteriden, 1842, p. 62.

***Gymnasteria carinifera* (Lamarck).**

*Asterias carinifera* Lamarck, Animaux sans Vertèbres, t. II, 1816, p. 556.

*Gymnasterias carinifera* v. Martens, Archiv. f. Naturg., Jahrg. xxxii, Bd. 1, 1866, p. 74.

This species is recorded from the Sandwich Islands by Perrier (Révision des Stellérides, p. 286), the specimens being in the British Museum. Sladen likewise records it in the report on the starfishes collected by the *Challenger* expedition (p. 357), very likely from the same specimens. No examples were secured by the *Albatross* expedition.

**Order SPINULOSA Perrier emended.****Family ASTERINIDÆ Gray, 1840 (emended).**

Asterinidæ Gray, Synopsis of the Genera and Species of the Class *Hypostoma* (*Asterias* Linn.). <Ann. N. H., ser. 1, vol. vi, 1840, p. 288. Emended by Perrier, Révision des Stellérides, 1875, p. 289; and in Mission Scientif. du Cap Horn, Echinodermes, 1891, p. 107.

= Asterinidæ Sladen, Challenger Asteroidea, 1889, pp. 376, 384, or the Asterinidæ, less Ganeriinæ and Palmipedinæ.

**Genus ASTERINA Nardo.**

*Asterina* Nardo, De Asteriis, Oken's Isis, 1834, p. 716. Type (?) *Asterina gibbosa* (Pennant). *Asterina minuta* (Oliv.) Nardo = *Asterias gibbosa* Pennant.

***Asterina granulosa* Perrier.**

*Asterina granulosa* Perrier, Révision des Stellérides, 1875, p. 312. J. E. Ives, Proc. Phil. Acad. Sciences, 1889, p. 173.

The specimens upon which the species is based were collected by M. Ballieu in the Sandwich Islands in 1874. The only other direct reference which I have been able to find is that of J. E. Ives (l. c.), who records one specimen from Oahu, collected by Dr. W. H. Jones. No examples were secured by the *Albatross* expedition.

**Family ANSEROPODIDÆ<sup>a</sup>, new.**

= Subfamily Palmipedinæ Sladen, Challenger Asteroidea, 1889, p. 394.

<sup>a</sup>By those who do not believe that this group constitutes a family the name Anseropodinæ must be used, instead of Palmipedinæ, *Palmipes* being a synonym of *Anseropoda*.

Genus *ANSEROPODA*<sup>a</sup> Nardo.

*Anseropoda* Nardo, De Asteriis, Oken's Isis, 1834, p. 716. Type *Anseropoda membranacea* = *Asterias placenta* Pennant.  
*Palmipes* L. Agassiz, Mem. Soc. Sci. N. Neuchâtel, t. 1, 1835, 192.

*Anseropoda insignis*, new species.

Pl. xxxviii, figs. 1-1a.

Rays 6.  $R = 121$  mm.;  $r = 100$  mm.  $R = 1.2 r$ . A larger but less perfect specimen measures  $R, 127$  mm.;  $r, 97$  mm.  $R, 1.3 r$ .

The rays are thus very short, but have a well-rounded, leaf-like contour, the interbrachial arcs being also rounded. Tip of ray more or less indented. Body very thin and flat, slightly convex in center of disk, there being an abrupt, slightly elevated, rounded ridge along each medio-radial line.

Abactinal plates of interradial areas bear 1 fairly large tuft of very delicate, sharp spinelets, with usually 1 to 3 or more tufts of smaller size around it. On interradial areas of outer half of disk there is usually 1 but one tuft of about 7 to 10 spinelets, situated rather nearer the inner edge of plate than the center of exposed surface. Then, regarding toward radial areas and center of disk, there are added at either side first 1 and then 2 additional smaller tufts, which have 4 or 5 spinelets, while the large tuft has 7 to 10 or more. Occasionally the 3 merge and form a larger irregular tuft. Toward central portion of disk there are often 4 tufts of nearly equal size, with about 8 to 10 spinelets in each, situated on the four corners of a plate, with several groups of 1 to 3 spinelets scattered between. Other plates are irregular as to their armature, and the larger plates of the central or slightly elevated portion of disk have as many as 15 to 20 tufts of various sizes, mostly well spaced, and easily counted, but very irregular as to position. All spinelets are very delicate, sharp, and small, and are usually directed away from center of disk. On either side of median radial line there is a single series of numerous papulae, which do not quite reach to tip of ray nor to center of disk. The 2 series of a ray are separated by 2 longitudinal series of plates, larger than those immediately adjacent. They also bear more tufts of spinelets, usually 5 to 6.

Adambulacral plates are rather short, with a convex margin to furrow. Armature as follows: (1) A furrow series of 5 or 6 (rarely 4) delicate spinelets, united for over half their length by a thin web. They form a fan-shaped series, the median spinelet being slightly longer than the laterals. Sometimes the adoral spinelet, or less commonly, the aboral, is about two-thirds the length of the others, which are nearly equal. (2) On actinal surface of the plate a group of about 10 spinelets, united by a web and disposed in a curvilinear series, which is more easily understood from the accompanying figure (pl. xxxviii, fig. 1) than from description. A portion of this series—that nearest furrow—is usually directed backward, covering the outer spinelets of the group.

Mouth plates are fairly large, rather narrow outwardly. The armature consists of a marginal row of about 8 flattened, blunt spinelets, the basal half constricted and united by a thin web. They increase in size toward the inner angle, the innermost 3 to 4 spinelets being fairly stout, compressed and truncate. On actinal surface there is a double series of about 12 to 30 slenderer spinelets, extending lengthwise of the plate, or in a group of 5 or 6 parallel with furrow spinelets, the remainder, somewhat smaller and more delicate, being on the outer part of plate. There is much irregularity in the disposition of these spinelets.

Actinal plates bear a regular and ornate comb of delicate spinelets, connected for two-thirds or three-fourths their length by a thin but resistant web. The plates, and consequently the spines, decrease toward margin, and from the ambulacral furrow toward median interradial line. The innermost plates bear a series of 10 to 14 spines. Midway to extremity of ray, adjacent to furrow, there are about 9, but midway on the interradial line there are but 7 or 8, considerably shorter. Near margin the number is further reduced to 5 or 6. The median spinelets are longest and all radiate, forming plamate series.

<sup>a</sup>This genus has usually been called *Palmipes*. *Palmipes*, however, was not used by a post-Linnæan writer until a year after *Anseropoda* Nardo. It seems somewhat discouraging in the first years of the twentieth century to be obliged to call attention to the fact that Linck (1733), who first used *Palmipes* and who was quoted in the last extensive paper on European starfishes as the authority for the name, was in no way a binomial writer, and that consequently his so-called genera (!) have no place even if 1758 had not been agreed upon as the starting point of zoological nomenclature. For a statement of the facts in the present case see Prof. F. Jeffrey Bell in *Annals of Natural History*, ser. 6, vol. vii, 1891, p. 233. The Rev. Canon A. M. Norman (op. cit., p. 382) admits that *Anseropoda* has priority, but objects to its use because it happens to be etymologically a hybrid. What would happen if all generic names which confess this fault were thrown out for the same reason?

Marginal plates are very small. The plates which probably represent the superomarginals are larger than adjacent abactinal plates, and are placed without reference to the regular rows of the latter. They bear a tuft of minute spinelets. The inferomarginals are larger than superomarginals, and likewise bear a glomerular tuft of minute spinelets. Both series resemble tiny paxillæ.

Madreporic body small, situated near center of disk. Striations coarse, irregular, radiating. Anal opening subcentral 8 to 9 mm. from madreporic body. Ambulacral feet with small sucking disks.

Color in life: Upper surface bright vermilion, with a madder-pink cast, the 6 radial ridges intense scarlet vermilion. Actinal surface scarlet vermilion, a large area in central part of disk cream color, slightly spotted with vermilion. Edge of ambulacral furrow slightly more yellowish than rest of light patch. Ambulacral feet translucent yellowish brown (raw sienna).

Variations: A small specimen (R=35 mm.) is essentially like the large individuals. Most of the plates of the abactinal interradial area bear but 1 tuft of spinelets, 7 to 10 in number, and widely radiating. The larger plates of central portion of disk bear 4 to 8 tufts. Mouth plates shorter than in adult, and the furrow spinelets much slenderer, 5 to 6 in number, and united by a web. Actinal mouth spines fewer. Adambulacral furrow spines 5 or 6 at base of furrow, 3 or 4 on outer part.

Localities: Type (no. 21180, U. S. National Museum) from 4101, Pailolo Channel, between Maui and Molokai islands, 143-122 fathoms, coral sand, shells, foraminifera; bottom temperature 59.7°; 3 specimens. Taken also at 3835, south coast of Molokai, 169-182 fathoms, fine brown sand and mud; 1 specimen.

This remarkable starfish, which is a true *Anseropoda*, is perhaps the oddest species in the Hawaiian collection. Like its congeners, it is literally flatter than a pancake, which character, added to its brilliant coloring, gives it a truly bizarre appearance. The animal is very delicate on account of its extreme thinness. All the specimens are more or less injured, but the type is entire. *Anseropoda insignis* is probably nearest *A. placenta* of the Mediterranean region. It differs, however, in having constantly 6 rays, and in details of adambulacral and abactinal armature. *A. rosacea*, from Japan and the Bay of Bengal, is a fifteen-rayed form, which likewise differs in its armature. *A. diaphnea* (Sladen) and *A. pellucida* (Alcock) are apparently widely different forms.

This species evidently feeds largely upon shrimps, for the stomachs of 2 individuals are crammed with these small crustaceans ranging from 5 to 25 mm. in length. It would be interesting to learn in what manner the prey is secured.

#### Family ECHINASTERIDÆ Verrill, 1871, emended.

Echinasteridæ Verrill, Trans. Conn. Acad., vol. 1, 1867, part 2, p. 343.

##### Key to Hawaiian genera of Echinasteridæ.

- a. Disk small. Spinulation small. Spinelets isolated or grouped. No pedicellariæ.  
 b. Abactinal plates bearing small spinelets in more or less compact groups ..... HENRICIA  
 bb. Abactinal plates bearing simple isolated spines ..... ECHINASTER  
 aa. Disk moderately developed. Rays 5. Abactinal plates regularly disposed, having small isolated spinelets. Marginal plates with large valvate pedicellariæ. Actinal intermediate plates bearing one or more large flattened spinelets..... VALVASTER

#### Subfamily ECHINASTERINÆ VIGUIER, 1878.

Echinasterinæ Viguer, Anatomie Comparée du Squelette des Stellérides. <Archiv. Zool. Expér. et Génér., t. VII, 1878, p. 123 (separate).

##### Genus HENRICIA Gray.

*Henricia* Gray, Ann. N. H., ser. 1, vol. VI, 1840, p. 184. Type *Asterias sanguinolenta* O. F. Müller.

*Linckia* Forbes, nec Nardo, Mem. Wern., vol. VIII, 1839, p. 120.

*Cribrella* Forbes, nec Agassiz, British Starfishes, 1841, p. 106.

*Cribrella*, Lütken, Grönl. Echinod., 1857, p. 30; and most other authors up to present day.

*Echinaster*, Müller and Troschel, System der Asteriden, 1842, p. 22 (pars).

*Henricia*, Bell, Ann. N. H., ser. 6, vol. VI, 1890, p. 472.

Prof. F. J. Bell (op. cit.) has explained why the name *Cribrella* can not be used for this genus. Since few writers have cared to follow the ordinary rules of nomenclature in this case, however, it may be well to state again why *Cribrella* has no status in nomenclature.

L. Agassiz (Prodrome d'une Monographie des Radiates ou Echinodermes, Mém. Soc. Sci. Nat. Neuchâtel, t. 1, 1835, p. 191) wrote as follows:

LINCKIA Nardo.—*Cribrella* Ag. Msc.—Corps étoilé; rayons tuberculeux et allongés; peau poreuse dans les intervalles. *L. variolata* N. (*Asterias variol.* Lam.)—*L. Typus* N.—*L. Franciscus* N. Les especes décrites par Goldf. sous les noms d'*Asterias arenicola* et *abtusca*, semblent devoir former un genre à part que l'on pourrait nommer PLEURASTER. Je ne les connais cependant pas assez pour en decider.

It is very evident that *Linckia* and *Cribrella* were the same in Agassiz's mind. In other words, *Cribrella* must be treated as a substitute name for *Linckia* Nardo, and since *Cribrella* is based on *Linckia* the type of *Linckia* is the type of *Cribrella*. If *Linckia* should become invalidated, *Cribrella* could replace it; otherwise *Cribrella* can never have any standing other than as a synonym of *Linckia*. Even if none of the species given above were congeneric with *Linckia* of Nardo [but *L. typus* is the type of *Linckia*], or even if it could be proved that Agassiz never saw a specimen of true *Linckia*, the case would not be altered. If a writer bases one genus upon another intentionally or unintentionally, the type of the old genus becomes ipso facto the type of the new one.

It appears, therefore, that Forbes's appropriation of the name *Cribrella* for the group previously named *Henricia* by Gray has no justification. *Cribrella*, as a matter of fact, has nothing to do with this group. It is simply a synonym of *Linckia*. Canon Norman (Ann. N. H., ser. 6, vol. VII, p. 382) contends that "Agassiz first used the name; that Forbes more accurately defined the genus." Agassiz left no doubt as to what he meant by *Cribrella*, so that Forbes did not better matters by transferring the name to another and previously named genus.

*Key to Hawaiian species of Henricia.*

- a. Rays short and thick.....*robusta*  
 b. Rays long and slender.....*pauperrima*

***Henricia robusta*, new species.**

Pl. xxxv, figs. 1, 2; pl. xxxviii, figs. 2, 2a.

Rays 5. R=31 mm.; r=6 mm. R=5 r. Breadth of ray at widest part, near base, 8-9 mm. Rays unequal, the shortest with R=26 mm.

Rays short and stout, swollen at base, and thence tapering to a blunt extremity which is recurved. The whole animal is slightly depressed, so that the rays are not cylindrical except near tip, but are rather elliptical in section, and are constricted next to disk, a shallow sulcus running part way toward center of disk from each interradial angle. The disk appears rather small in consequence.

Plates of the abactinal surface are very small, and are so arranged as to form an open network, inclosing fairly large, irregular papular areas. These plates are crowded with groups of 3-8 minute, delicate, slender, short, cylindrical, often slightly tapering, spiculiform spinelets. There is no constant arrangement of these spinelets, although occasionally a biserial grouping is discoverable. Often they form an irregular circular group. The papular areas, which are sunken considerably, are often broken up by isolated plates, or 2 or 3 plates together, bearing tufts of spicules.

Low on the lateral wall, which is rounded, is a narrow, rather irregular longitudinal line, which rises toward interbrachial angle. This is composed of longitudinally disposed plates a trifle larger than the others, each crowned with 14 or 15 of the slender spinelets. Below this series is a similar line of smaller, transversely disposed plates, which is succeeded by still another longitudinal series, with long axis of plates likewise transverse. These bear about 15 spinelets disposed in 2 or 3 irregular transverse rows. The first series, which has been considered the superomarginal, is slightly more conspicuous than the lower (inferomarginal) because its plates are nearer together, being placed end to end. Between superomarginals and adambulacrals the plates are arranged in definite transverse series, except at very base of the ray, where there is irregularity. Between the inferomarginals and adambulacrals one can count 5 or 6 plates to each transverse series at base of ray. These are reduced to 2 at the end of the proximal third of ray, and to 1 at about the middle. The single longitudinal series of intermediate plates continues for two-thirds to three-fourths the length of the ray. These actinal plates are beset with slender spinelets like those of the dorsal plates. In some cases a delicate web can be distinguished uniting the basal half of several adjacent spinelets.

Armature of adambulacrals plates as follows: (1) A short compressed spinelet placed high up on side of furrow. (2) On actinal surface of plates at base of ray, 3 or 4 larger, cylindrical, slightly taper-

ing spinelets, arranged with 1 on furrow margin and 2 behind in an oblique or longitudinal series; or when there are 4, 1 on margin, followed by 1 directly behind it, and the two outer in an oblique series. Occasionally the 4 are grouped on the inner half of plate, without definite order. On outer part of plate there is a group of 7 to 10 much smaller, subclavate spinelets, slightly larger than those of adjacent actinal intermediate plates. They are well spaced, and increase in length toward furrow. Further along ray the arrangement is usually 1 spinelet on the furrow edge and behind it, 2, a trifle shorter, in a longitudinal series. A fourth spinelet is sometimes present, external to these. On the outer side of plate are 5 or 6 unequal, smaller spinelets, their bases united by membrane.

Madreporic body of medium size, circular, situated at the summit of an interradial sulcus. Striations few, coarse, radiating, with wide sulcuses between the ridges. The latter are studded with numerous spinelets, like those of neighboring plates. Anal opening eccentric, prominent.

Color in life, a soiled cream color.

Locality: Type (no. 21181, U. S. National Museum) from station 4115, northwest coast of Oahu Island, 195-241 fathoms, coral sand, foraminifera; bottom temperature 55.1°.

This species is characterized by its thick, short rays, and generally robust form, by the uncrowded condition of the plates which form a network, by the numerous delicate spicules forming groups on these plates, and by the adambulacral armature. The species is most nearly related to *Henricia obesa* (Sladen) from the Falkland Islands and Straits of Magellan, from which it differs in details of its spinulation and in the armature of the adambulacral plates. The spines of the body are much more delicate in *robusta* than in *obesa*, and are more numerous.

#### *Henricia pauperrima*, new species.

Pl. xxxv, figs. 3, 4; pl. xxxviii, fig. 3, 3a-b.

Rays 5. R=61 mm.; r=9 mm. R=6.7 r. Breadth of ray at base, 9 mm.; at 10 mm. from base, 6 mm. Rays unequal, the shortest (possibly mutilated) 40 mm.

Rays long and very slender, cylindrical, tapering continually from a narrow base to a prolonged, bluntly pointed extremity. Disk fair sized, somewhat inflated. Interbranchial angles obtuse or rounded.

Plates are larger and more crowded than in the foregoing species. They are small and form a close network which is very irregular. Abactinal surface, however, appears quite porous, the plates being in nowise so crowded as in *leviuscula* or *sanguinolenta*. Papulae are large and isolated, surrounded by small plates, which bear 8 to 12 minute, very delicate and sharp, well-spaced spinelets. These are much more delicate than those of last species and can not be distinguished without a glass. Smaller plates may bear only 4 or 5 spicules, which, however, are always spaced, not in compact groups.

Adjacent to the adambulacral plates is a series of plates slightly larger than the lateral and abactinal plates, and like them bearing delicate spinelets. On the outer two-thirds of the ray a continuous series of smaller (superomarginal?) plates is present, and between the 2 is a very definite line of papulae which extends to mouth angle. Actinal interradial plates are rather larger than abactinals.

Adambulacral plates are rather large, only a trifle broader than long. Armature as follows: (1) 2 delicate, slender spinelets, placed one above the other high on furrow wall, the upper being at apex of plate. (2) On actinal surface 3 rather long, slender spinelets, spaced on edge of furrow, 1 in the center being longest. Just behind these, at the base of ray, 2 to 4 additional spinelets often stand in a longitudinal row, and occasionally farther along the ray there will be 1 or 2 much smaller spinelets. The outer two-thirds of the plate is covered with 10 to 15 delicate, minute, well-spaced spinelets or spicules, similar to those arming other plates of the body.

Madreporic body fairly large, with a few coarse, irregular, narrow ridges separated by deep sulcuses. Ridges bear minute spinelets. Body is situated nearly midway between center of disk and margin when the specimen is viewed directly from above.

Color in life, very pale greenish-gray or dirty white; ambulacral furrows darker greenish-gray.

Localities: Type (no. 21182, U. S. National Museum) from station 4166, vicinity of Bird Island, 293 to 800 fathoms, coral sand, foraminifera, rocks; bottom temperature 45.6°. A young specimen probably belonging to this species was taken from 4044, west coast of Hawaii, 233 to 198 fathoms, fine gray sand.

This species is remarkable for its very slender rays, and curiously formed disk. It is probably most closely related to *Henricia compacta* (Sladen), from the west coast of New Zealand (275 fathoms), but differs from this form principally in the adambulacral armature. *H. pauperrima* may be readily distinguished by the 2 small spines placed on the side of the ambulacral furrow (pl. XXXVIII, fig. 3b), there being in this genus usually only 1.

**Genus ECHINASTER Müller and Troschel.**

*Echinaster* Müller and Troschel, Monatsber. d. k. preuss. Akad. d. Wiss. Berlin, April, 1840, p. 102. Type (?) *Echinaster sepositus* (Lamarck).

***Echinaster*, sp.**

Of the 2 species of *Echinaster* in the collection, 1 is represented by 2 specimens, the other by but 1. The first species is too young for specific determination. One of the examples was taken at station 3872, Auau Channel, 43 to 32 fathoms, yellow sand, pebbles, coral; the other at station 4162, Bird Island, 21 to 24 fathoms.  $R=13$  mm.,  $r=2.75$  mm. The plates are relatively large, cordate, and arranged on rays in a radial, adradial, supero- and inferomarginal and 1 actinal intermediate series. The primary apical system is conspicuous. In the smaller of the two specimens most of the plates have a short stubby spinelet. Furrow adambulacral spinelets 2, short, the aboral slightly the shorter; arranged in a linear series, the whole of which from end to end of the ray is invested in a very delicate membrane. On the actinal surface of every adambulacral plate is a robust, short, stubby, lanceolate spine directed away from furrow. On outer part of ray alternate plates are often without actinal spines. Actinal intermediate plates much smaller than inferomarginals, oval in shape, and about as large as adambulacral plates. Single madreporic body. Rays 5.

Color in life: Light buff, yellow at tips of rays, which are mottled above with burnt sienna. The rays are also marked with transverse scalloped lines of the same color, which follow the adoral overlapping edges of the plates and give a very scaly appearance to the creature.

The other species is larger and is almost undoubtedly new, but is in rather too poor condition to constitute a type. It is closely related to *Echinaster sladeni* de Loriol, from Mauritius.<sup>a</sup> Rays 5.  $R=32$  mm.;  $r=5$  mm.  $R=6.4$  r. Rays considerably flattened, somewhat constricted at base, tapering to a blunt point; practically the same shape as *E. sladeni*. There are 7 longitudinal series of 4-lobed plates, of which the marginal series is constantly most regular. Each plate, with few exceptions, bears a robust, sharp spinelet only very microscopically striated. Between adambulacral and inferomarginal series are 2 rows of small rounded plates, the outer series corresponding plate to plate with the inferomarginals, while there are 2 plates of inner series to each of the outer. Papular areas about size of plates, containing only 1 or 2 papulae. Adambulacral plates short, band-like. Furrow spinelets 2, rather delicate, slender, blunt, tapering very slightly. They are united for most of their length by a very delicate membrane which is continuous throughout ray. On actinal surface is a robust, slightly flattened, tapering, bluntly pointed spine, somewhat larger than those of inferomarginals. Occasionally a plate is missed, and on the outer part of ray usually only alternate plates possess an actinal spine. Madreporic body single.

Locality: Station 4046, west coast of Hawaii, 147 to 71 fathoms, coral sand, foraminifera.

It is possible that the preceding species is the very young of this form. The present species differs from *sladeni* in having a thicker skin, stouter spinelets which do not appear to be striated as in the Mauritius species; very much heavier actinal adambulacral spines, and more cylindrical, blunter furrow spinelets, which are, moreover, webbed. The 2 series of adambulacral spines will distinguish this species from *E. gracilis*, *E. eridanella*, and the other Indian and Pacific forms, if taken in connection with the thinnish skin and regular rows of plates.

**Subfamily VALVASTERINÆ Viguier, 1878.**

Valvasterinæ Viguier, Anatomie Comparée du Squelette des Stellérides. <Arch. Zool. Expér. et Génér., t. VII, 1878, p. 131 (separate).

**Genus VALVASTER Perrier.**

*Valvaster* Perrier, Révision des Stellérides, 1875, p. 112. Type, *Asterias striata* Lamarck.

<sup>a</sup> Mem. Soc. Phys. et d'Hist. Nat. Genève, t. XXXII, pt. 1, 1894, p. 61, pl.

*Valvaster striatus* (Lamarck).

Pl. xxxviii, figs. 4, 4a.

*Asterias striata* Lamarck, *Animals sans Vetrebres*, t. III, 1816, p. 253.*Valvaster striatus*, Perrier, *Révision des Stellérides*, p. 112, q. v. for complete synonymy.

This species was not taken by the *Albatross* in 1902, but a specimen was secured in 1891 at station 3469, south coast of Oahu Island, in 14 fathoms, on sand and coral.

A very good figure, with critical and descriptive notes, is given by P. de Loriol in "Catalogue Raisonné des Echinodermes recueillis à l'Isle de Maurice" (II. Stellérides), published in *Mémoires de la Société Physique et d'Histoire Naturelle de Genève*, t. xxix, 1885, p. 11, pl. VIII.

Rays 5. R=50 mm.; r=18.5 mm. R=2.8 r. Breadth of ray at base about 22.5 mm. General form depressed and flattened. Interbrachial arcs angular. The whole surface of the body is covered with short robust spines and spinelets, which are sharp on the abactinal surface but more blunt and often rounded, truncate, and flattened on the actinal. The characteristic feature of the species is a series of very large superomarginal, valvate pedicellariæ, surrounded by acicular spinelets, bordering the abactinal area.

Abactinal surface slightly inflated and the plates, which are arranged in regular network, leaving triangular, rather small, papular spaces, are not superficially evident in the alcoholic specimen. They are covered with sharp, conical spinelets, each of which is enveloped in a pulpy membranous investment, so that neighboring spinelets appear to touch, and do not appear isolated as in the dried specimen figured by de Loriol. A median radial and 2 parallel series of spinelets on either side are slightly more prominent than the others. The small papular areas have fewer pores than de Loriol's specimen, only about 3 to 5. The abactinal membrane is granulous.

The superomarginal plates visibly define the border of the ray. Nearly all of them bear a long bivalved pedicellaria which occupies the whole length of plate and is surrounded by small, sharp, slightly curved acicular spinelets invested by a pulpy membrane which obscures entirely the encased spinelets. In interbrachial angle and at extremity of ray, a few plates lack the pedicellaria and bear an enlarged spinelet surrounded by granules and small, sharp spinelets.

Actinal plates bear each a flattened, stout, sharp, blunt, or truncate spine, much larger than the dorsal spinules. These spines, which are encased in membrane, are surrounded by 2 to 5 unequal, much smaller acicular spinelets, which are so sheathed in membrane as to appear broadly conical. The smallest of these spinelets is one-third the size of the largest, and there are likewise still smaller granules, especially in the interradial region. There are 5 longitudinal rows of the spines at base of ray, then 4 and 3, and on the outer third of ray 2. Inferomarginal plates each bear a stout, tapering, flattened spine, larger than the actinal spines, surrounded by a number of membrane-invested small acicular spinelets, 1 or 2 of which are usually larger than the others. Rarely a second spine stands on the same plate with the first. In de Loriol's specimen from Mauritius 2 spines were usual, and occasionally 3. Each adambulacral plate, clearly distinct from its neighbor, bears a furrow series of 5 spinelets at base of ray, becoming reduced to 3 on the outer portion. They form a fan, the aboral spinelet being equal to the third and the spinelet between them a trifle longer, while the fourth and fifth are decreasingly shorter than third. They are united by membrane for one-half to two-thirds their length, and are slender, the longest being about 1.75 mm., the shortest 0.25 mm. On the actinal surface of plate stands a truncate, flattened, slightly tapering, much stouter, and longer (2.5 mm.) spine similar to those of actinal intermediate plates. Two or 3 granules and a small, sharp spinelet stand close to its base in the outer end of plate. On a number of the proximal plates of series a small, upright, blunt forciform pedicellaria takes the place of the shortest spinelet. A very few plates have a sixth spinelet or granule added to the adoral end of the series.

Madreporic body small, and situated nearer the center of disk than midway to margin. Striations very fine.

The specimen was partially dried after the characters had been noted in the alcoholic condition. In this way the granules of the abactinal surface became at once evident, and likewise a very few small forciform pedicellariæ. The character of the abactinal surface agrees very well with de Loriol's figures, except that the spines are a trifle stouter than in the Mauritius specimen, and, since our specimen is smaller, the papular pores, as already noted, are fewer. The actinal spines of the Hawaiian example are not so broadly truncate, but are frequently slightly tapering and even bluntly

pointed. The accompanying spinelets appear a trifle larger and stouter in proportion to spine. The furrow spinelets are slightly stouter than in de Loriol's specimen, and there is usually but 1 acicular spinelet accompanying the actinal adambulacral spine. De Loriol does not mention the furrow pedicellariæ, which are present in the Hawaiian specimen. Some of these differences, all of which are slight, may be due to age, but more likely to the widely separated localities.

*Valvaster striatus* in another widely distributed form. It is found at Mauritius, but there is a great scarcity of records for points intermediate between that island and the Hawaiian group, for I have been unable to find any.

#### Family MITHRODIDÆ Perrier, 1894.

Mithrodidæa Perrier, Expéd. Travailleur et Talisman, Echinodermes, 1894, p. 4.

= Mithrodiinæ Viguièr, Anatomie du Squelette des Stellérides. <Arch. Zool. Expér. et Génér., t. VII, 1878 (1879), p. 128.

#### Genus MITHRODIA Gray.

*Mithrodia* Gray, Ann. N. H., ser. 1, vol. VI, 1840, p. 287. Type, *Mithrodia spinulosa* (= *Asterias clavigera* Lamarck).

*Heresaster* Michelin, Révue Zoologique, 1844, p. 173.

#### *Mithrodia bradleyi* Verrill.

Pl. XXXVI, figs. 1, 2; pl. XXXVII, figs. 1, 2, 3.

*Mithrodia bradleyi* Verrill, Trans. Conn. Acad., vol. 1, 1869, p. 289.

*Mithrodia clavigera* Perrier, Révision des Stellérides, 1875, p. 817; see also p. 337. J. E. Ives, Proc. Philad. Acad. Sci., 1889, p. 171.

This peculiar type is a rather common inhabitant of coral sand and rocks in shallow water, but so far as our experience goes is not found on exposed reefs anywhere in the Hawaiian group. Nearly all the specimens were taken with hempen tangles from bottom too rough for dredging nets. On account of the stout, rough spines with which the sides of the body are beset this method of collecting proved very successful, a considerable number of perfect specimens having been secured. These exhibit some variation not altogether due to difference of age.

The largest example has a major radius of 230 mm., or a diameter of about 450 mm. Not all the rays are of equal length, one being larger than all the rest. The shortest ray is about 198 mm. Inequality of rays seems to be a characteristic of the species. There are generally 5 rays, but one small specimen has 4 and another 6.

Rays subcylindrical, broader than high, except in young specimens where dimensions are nearly equal; distinctly narrowed at base and constricted next to the very small disk.  $R \approx 14r$ , but in one large specimen the ratio is as low as 1 to 8.5 or 9. The whole animal is covered with a tough integument beset with rather sharp granules, beneath which are the plates, so arranged that the surface of the body is marked off by coarse ridges forming a sort of network, which isolates triangular, roundish, or irregular areas containing the papule and covered with tiny scattered granules. The ridges are thrown into little knobs or prominences which vary considerably in number and proportions. As a rule they are more numerous in large specimens, often so much so as to destroy the mesh-like appearance of the ridges, which are covered with low, conical, crowded granules that give a very rough, rasp-like texture to surface. There are no prominent spines on the dorsal surface except in young specimens and very rarely in medium-sized specimens. In the former there is usually a median radial series of 6 or 8 widely spaced, rigid, subconical, or elongate thimble-shaped spines covered with sharp, scale-like granules. The granules or asperities on summits of the lower knob-like eminences, as well as those of the spine-tips, are larger and sharper than the others. There are regularly in old and young 3 longitudinal rows of cylindrical rigid spines, like those just described, on either side of the body, 1 on the margin or lateral face of ray, and the other 2 on the actinal surface. In adults the spines of the lateral series are least numerous, while those of the innermost ventral series are most numerous as well as slightly the smallest. In small and medium-sized examples there is not much difference between the middle (or outer ventral) and inner series, while in some adults there is considerable difference. These spines are slightly tapering and the membranous integument covering them is invested, like that of remainder of body, with squamiform,

<sup>a</sup> Although Perrier considered this an independent family in 1884 (Mém. sur les Etoiles de Mer, p. 164), he wrote the name "Mithrodingæ."

pointed granules, larger and more crowded at tip than at base. In 1 specimen a secondary row of enlarged tubercles intervenes between the 2 actinal rows of spines.

Each adambulacral plate bears a prominent cylindrical, blunt, upright spine on the actinal surface. These form a regular, close series at border of furrow, and are slenderer, slightly shorter and much more numerous than the adjacent spines of inner actinal series. (In young specimens the difference between the 2 series is very marked.) They taper very slightly, have rounded tips, and are covered with squamiform granules, which increase in size toward extremity of spine; but on side toward furrow there are no granules except at the very tip, the surface being smooth. Furrow series is placed directly at the base of the large actinal spine and consists of 6 to 9 or 10 slender spinules, united for their whole length by a fairly tough membrane and forming thus a fan with a very convex margin. The 3 or 4 central spinules are much the longest, the outermost of each series being very short indeed, especially when there are 8 to 10 spinelets to each fan.

Madreporic body is of medium size, with rather fine, interrupted striations. It is situated about midway between center and margin of disk, and in the larger specimens is nearly completely obscured by protuberances of the test.

The color of the live animal varies somewhat. One medium-sized individual was uniform vermilion except ambulacral furrow, which is yellow ocher. A large specimen was colored as follows: Papular areas dull brownish or reddish gray (a sort of pinkish sepia); abactinal surface of arms with 6 or more dark, or brownish, cross bars; the tubercles of lighter bars light vermilion; on the dark cross bars, deep vermilion. On actinal surface no barring visible, the tubercles and spines being all bright vermilion. Suckers of tube feet, yellow.

Localities: Thirty-six specimens were taken at the following localities, station 4024 with 9 being most prolific.

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
		<i>Fathoms.</i>	
3847.....	South coast of Molokai.....	23-24	Sand, stones.
3871.....	Auau Channel between Maui and Lanai.....	13-43	Fine white sand.
3872.....	do.....	43-52	Yellow sand, pebbles, coral.
3876.....	do.....	28-43	Sand, gravel.
3960.....	Vicinity of Laysan.....	10-19	Sand, shells, coral.
3975.....	Necker Island Shoal.....	16-171	Coarse sand, coral, shells.
3978.....	Vicinity of Bird Island.....	32-46	Coral sand, foraminifera, rocks.
4024.....	Vicinity of Kauai.....	24-43	Coarse coral sand, foraminifera.
4034.....	Penguin Bank, south coast of Oahu.....	28-14	Fine coral sand, foraminifera.
4046.....	West coast of Hawaii.....	147-71	Coral sand, foraminifera.
4062.....	Northeast coast of Hawaii.....	83-113	Coral, volcanic sand, shells.
4146.....	Vicinity of Bird Island.....	23-26	Coarse coral sand.
4159.....	do.....	30-31	Coarse coral sand, broken shells, foraminifera.
4160.....	do.....	31-39	Coral, coralline.
4162.....	do.....	21-24	Coral.
4163.....	do.....	24-40	Do.
4164.....	do.....	40-56	Coral sand, pebbles, shells.
4169.....	do.....	21-22	Coral.
4170.....	do.....	26-27	Coral sand, foraminifera.

I have compared the Hawaiian specimens with 2 full grown examples of *bradleyi* from the Gulf of California and a specimen of *clavigera* from the Fiji Islands. The latter, in the collection of the California Academy of Sciences, was taken by A. Garrett, and is labeled *Mithrodia spinulosa* Gray. This example is considerably different from any of the Hawaiian specimens. The rays are slenderer, meshes of the skeleton wider, the trabeculae slenderer, and the granulation of the integument much finer. There is a median dorsal row of spines, which are widely placed beyond the middle of the ray and are few in number. The other spines are all relatively longer than in Hawaiian specimens, with the exception of the adambulacral armature. The trabeculae have numerous small, spaced, tubercles which are not swollen and crowded as is often the case in the Hawaiian specimens. On the papular areas the granules are elongated into short spinelets of a rasp-like appearance. Furrow spinelets are 11, the central longest, and the 5 on either side graduated in length, the laterals being quite short. These are rather more delicate than in the Hawaiian examples, and decidedly more so than in those from the Gulf of California.

In *bradleyi* from the last locality the furrow spinelets range from 6 to 10, the central spinelets being slightly heavier and more clavate than in the Hawaiian examples. The number of spinelets is of not so great importance, since the Fiji example of *clavigera* has 11 (occasionally 10), while an example from Mauritius figured by P. de Lorient has but 8 and 9. There are no medio-radial spines in adult examples of *bradleyi* and all the spines appear shorter and stouter.

While the Hawaiian examples are not typical, they are certainly nearer *bradleyi* than *clavigera*. In the character of the furrow spinelets the specimens are nearly intermediate. Perrier in his *Révision des Stellérides* refers Hawaiian examples to *clavigera*, as noted in the synonymy, but later in the same work, under *Luidia brevispina*, says: "Si, comme j'ai quelques raisons de le croire les *Mithrodia* de Panama et des Sandwich sont spécifiquement identique, nous aurions donc deux especes d'Astéries communes à la côte occidentale d'Amérique et aux îles Sandwich" (p. 337). Evidently this authority had some doubts concerning the identity of the Hawaiian *Mithrodia*, and changed his mind after publishing the first part of his work.

To arrive at any satisfactory conclusions concerning the species of this interesting genus, one must have specimens from very many localities throughout its range, and preferably many specimens from each locality.

NOTES ON A PECULIAR SPECIMEN OF MITHRODIA.

Pl. XXXVII, figs. 2, 3.

There is one specimen in the collection which differs so widely from any of the others that it has not been included in the foregoing notes. R=140 to 145 mm.; r=33 to 37 mm. R=3.8 to 4.4 r. Disk rather large, rays stout, blunt, subcylindrical, heavy, not constricted at base, but on the contrary widening a little. Breadth of ray at base 35 to 40 mm. Interbrachial angles distinctly rounded. The ridges which are so conspicuous in the other specimens are scarcely perceptible in this, and are very much smaller and more numerous, dividing the body into irregular, very much smaller and more numerous papular areas. While in ordinary examples these trabeculæ are thrown into irregular and frequent prominences, in this specimen the whole surface of the body is covered with scattered, low, thimble-shaped tubercles. They arise abruptly from the inconspicuous trabeculæ, and are covered with small conical sharp granules very much larger than the tiny granules embedded in the rest of the integument. On the actinal surface there are 2 rows of these, larger than the rest, which correspond to the 2 actinal series in typical specimens, but the lateral row is entirely wanting. The spines of the innermost actinal series—that adjacent to the actinal armature of the adambulacral plates—are more numerous and larger than those of the outer row, which are almost wanting on one ray. The inner face of the actinal adambulacral spines is entirely covered with granules, is not naked as in typical specimens. There are 8 spinelets on the furrow series. Color in life, dull light cinnamon, pink and maroon at ends of arms. The cinnamon in places is mottled with buff. Actinal surface is light pinkish buff, or vinaceous, darkest on tubercles. Ambulacral feet raw sienna. The coloring is thus considerably different from the other specimens.

Young: There is a young example which seems to be near the above and which agrees with it very well in most particulars. The innermost actinal row of spines is very regular and straight, the spines themselves being shorter than those of the adambulacral series. There is also a second series of less numerous ventro-lateral, and a third series of lateral spines, all short, in addition to a few scattered on the dorsal surface. Actinal adambulacral spines and dorsal tubercles as in adult. R=38 mm.; r=12 mm.; breadth of ray at base, 14 mm.

Localities: Station 4147, Bird Island, 26 fathoms, coral and coralline; 4158, same locality, 20-30 fathoms.

Whether this is a different species from the common form, or only a freak, I am unable to state. If it is not a mere variation of *bradleyi*, it would apparently represent an undescribed species.

Family MYXASTERIDÆ Perrier, 1894.

Myxasteridæ Perrier, Expéditions Scientifiques du Travailleur et du Talisman, Echinodermes, 1894, p. 177.

Genus ASTHENACTIS, new.

Type *Asthenactis papyraceus*, new species.

Rays 7, long, flexible. Disk fairly large, capable of inflation. Actinostome very large and adambulacral furrows wide. Tube feet large, in 2 series, with sucking disks.

The whole abactinal and lateral surfaces of body are paved with very thin, delicate, papery plates, of a peculiar subcruciform or 4-lobed contour. They are immersed in thin, tough integument, and imbricate strongly, especially on sides of body, where they are arranged in fairly regular transverse rows. Individual plates are difficult to distinguish until the integument is dry. Each plate bears a sheathed tuft of spicules. Papulae single.

Adambulacral plates are of curious shape, set somewhat obliquely, so that the outer aboral process of each plate fits against the outer side of the succeeding plate. Armature consists of an oblique transverse series of long, slender spinules divided between 2 adjacent plates. That portion of the comb nearest furrow is set on an oblique low ridge of one plate, and consists of 7 spinelets, while the outer part of series stands on the aboral extension of the adjacent adoral plate and consists of 3 spinelets, the entire 10 being united to their tips by a continuous web. The outermost spinelet of consecutive series is further united by a longitudinal ventro-lateral membrane which is perforated between each adambulacral series of spines.

Mouth plates are prominent actinally, of the *Myxaster* type, with a prominent beak aborally, and a marginal armature united by membrane.

Madreporic body large, not multiple.

This genus differs from *Myxaster* in the following important particulars: In the peculiar arrangement of the adambulacral plates and their spines, each transverse series of the latter, although united by membrane as in *Myxaster*, being common to 2 adjacent plates; by the presence of a sort of actino-lateral membrane uniting the successive adambulacral series, this membrane being perforated; abactinal and lateral plates are thinner and more delicate than in *Myxaster*, are immersed in membrane, and are not so regular along medio-radial region.

***Asthenactis papyraceus*, new species.**

Pl. XL, figs. 3, 3a.

Rays 7. R=105 mm.; r=15 mm. R=7 r. Breadth of ray at base about 10-12 mm.

Rays long, and slender throughout, very flexible, tapering from a fairly narrow base to an attenuate extremity. They are subcylindrical, depressed near base. Margin of ambulacral furrow rounded. Disk fairly large and ambulacral furrows fairly wide. Ambulacral feet in 2 series, with prominent sucking disks. Integument like parchment, rather thin and papery, with numerous imbricating subcruciform plates.

Abactinal and lateral walls of body paved with very thin, delicate, papery plates of fair size, the 4 processes of each plate having rounded ends. Those at the sides of body are arranged in fairly regular transverse rows, and are rather closely imbricated. Here one can count about 4 or 5 plates to each transverse row. They imbricate in such a way that the upper edge of a plate overlies the lower edge of that just above. Their form and arrangement are perhaps best shown by the figure (pl. XL, fig. 3). Over abactinal area the plates may be described as stellate with 4 obtuse, often irregular lobes. They are not nearly so crowded as in the lateral walls, and do not appear to be regularly arranged, although they still imbricate by their lobes. Between these plates single small papulae emerge. They are very inconspicuous, and are present also between some of the lateral plates. All plates are thin and of an embryonic character, and their outlines are difficult to discern. When prepared and examined under the microscope, they are seen to consist of an open calcareous meshwork of the most delicate description. Each plate bears a tuft or brush of long, delicate spicules, 4 or more to each group, the whole united by a delicate sheath. Spines of lateral plates are situated on the middle of upper border of plate. Surrounding the conspicuous anal opening, at a slight distance, is a circle of 7 tufts, radially situated, and larger than any of the others. The spinelets or spicules are very delicate in all these groups. Each has a deep longitudinal sulcus running its whole length, in the bottom of which are numerous perforations forming about 2 series. The disk is marked by a faint groove extending from each interbrachial angle to the periproct. The whole surface of the body is covered with a thin membrane which obscures the outlines of the plates. This is continued up over the groups of spines, forming the sheath mentioned above.

Ambulacral plates form a rounded margin to furrow, and are of unusual shape. Each is rounded on its exposed surface and sends a process aborally, external to the adjacent aboral plate. This process, which is wedged between the succeeding plate and the first row of actinal plates, is really only the exposed surface of a more extensive aboral end, overlaid by the adoral end of the succeeding plate. Its greatest peculiarity lies in the fact that it bears a group of spinelets which form a continuous series, not with the furrow spinelets of their own plate, but with those of the succeeding plate, to which they

stand just external. Armature, therefore, consists of 7 (becoming 6 at about middle of ray) long, slender spinules, united by a delicate web, forming a slightly curved, transverse, oblique series, placed on a tumid ridge on the rounded furrow margin, trending from the aboral furrow side outward and adrad. Inasmuch as the plates are set obliquely the series is not far off the transverse axis. This series is immediately continued on the aboral process of the adjacent adoral plate in 2 or 3 long slender spinules, also placed obliquely. The spines of the two series are united from base to tip by a single, continuous, delicate web. On the proximal portion of rays (the distal part being too injured to verify the structure there) the outer groups of spines of successive plates are united by a delicate longitudinal membrane, as shown in the figure (pl. XL, fig. 3a). This membrane is perforated between successive transverse series, and extends across interbrachial area just behind mouth plates, there being also a perforation at the outer end of combined dentary plates. The spines of inner or marginal series decrease in size toward aboral end of series, the last or inner spinelet being short (1 to 1.5 mm.). The longest spines are about 5 or 6 mm. in length. Outer series is subequal or slightly longer than longest inner spines.

Mouth plates prominent actinally, and triangular in shape, something like a plowshare. Each rises toward a perfectly straight, median suture to form a prominent keel. Edge of plate toward actinostome is broad, faintly convex, and produced just a trifle at the median suture. The outer end of the combined pair is also prolonged, so that it overhangs interbrachial area. Margin adjacent to furrow very short, concave, and high in furrow. Distal (adambulacral) margin concave, the suture slightly raised, so that a broad furrow is present between the first adambulacral and the smooth actinal face of plate. Armature consists of a series of 6 spines and spinelets on margin toward actinostome. The inner 3 or 4 are rather long, reaching nearly to outer end of plate, and are united by a web. The outer 2 or 3 are very short. On the short margin adjacent to furrow, near the shorter marginal spinelets, are 2 upright spinelets about the same length as the latter. The general surface of the plates is quite smooth, and the spines, as well as those of the adambulacral plates, are similar in structure to the abactinal spines already described, although much larger and stouter. They are nevertheless very delicate, and break almost at a touch.

Madreporic body large, convex, subcircular, very fragile, situated rather nearer center of disk than midway to margin. Striations are obscure and very irregular. Ambulacral plates are large, with very broad ends, the upper ends especially flaring. The apertures between the plates are large.

Color in life, dull pinkish ("salmon pink").

Locality: Station 4157, vicinity Bird Island, 762-1,000 fathoms, white mud, foraminifera, rocks; bottom temperature 38°. Type no. 21183, U. S. National Museum.

#### Family PTERASTERIDÆ Perrier, 1875.

*Pterasteridæ* Perrier, Révision de la Collection de Stellérides du Muséum d'Histoire Naturelle de Paris, 1875, p. 381.

##### *Key to Hawaiian genera of Pterasteridæ.*

- a.* Armature of adambulacral plates forming transverse combs, the spines being united by a web.  
Actinolateral spines forming a free, independent lateral fringe; not merged in the actinal floor;  
supradorsal membrane with muscular fibrous bands.....PTERASTER
- aa.* Armature of adambulacral plates not forming transverse combs. Spines independent, not united  
by a web.
- b.* Nidamental cavity spacious. Supradorsal membrane well developed; spinelets of paxillæ not  
protruding through, but supporting the membrane .....HYMENASTER
- bb.* Nidamental cavity small; supradorsal membrane exceedingly thin; muscle fibers absent or rudi-  
mentary. Spinelets of paxillæ fascicular, protruding a great portion of their length naked  
through the membrane. Size small.....BENTHASTER

#### Genus PTERASTER Müller and Troschel.

*Pteraster* Müller and Troschel, System der Asteriden, 1842, p. 128. Type, *Asterias militaris* O. F. Müller.

#### *Pteraster reticulatus*, new species.

Pl. xxxviii, figs. 5, 5a; pl. xxxix, figs. 1, 2.

Marginal contour stellate. Interbrachial arcs angular. R=39 mm.; r=23 mm. R=1.7 r. Breadth of ray at base about equal to r. Disk not high. Abactinal surface rounded, sloping gradually to tip of ray. Sides of rays straight. Actinal surface sunken toward actinostome.

Supradorsal membrane thin but muscular; whole surface densely beset with the tips of paxillæ spinelets, which are very prominent though slender. Pedicels of paxillæ are rather longer than the spinelets, of which there are about 10 widely radiating to each group. There are apparently no spicules present in the membrane, which is marked off by a meshwork of muscular bands into polygonal or roundish areas. In the type these bands are not at all conspicuous; in fact, are rather indistinct, but in a specimen from station 3472 they are very well marked. In this specimen each area is slightly sunken, and is further broken up by the protruding tips of paxillæ spinelets, from which radiate numerous, much smaller, irregular fibers. On disk there are about a dozen large spiracula to each area, but on rays they are much less numerous. Ocular orifice large, but not conspicuous; surrounded by spines imbedded in membrane.

Ambulacral furrows narrow. Tube feet in 2 rows, with no tendency toward quadriseriate arrangement. Armature of adambulacral plates consists of a transverse series of 6 or 7 spines. The innermost spinule is short and slender, about one-half the length of the next, and is placed a little aborad to the remainder of comb, which thus appears to curve slightly at furrow end. Each succeeding spine is considerably longer than the last, the outermost being about one-half the length of adjacent actinolateral spine, on the proximal portion of ray, but considerably more than one-half on distal portion. All radiate and are joined by a thin, semitransparent membrane, with shallow emarginations between the tips of the spines. The web, after passing the outermost spine, is joined to the actinolateral membrane (or the web of the actinolateral spines) somewhat aborad to that lateral spine corresponding to the plate. The adambulacral web of the first plate is confluent, just external to mouth plates, with web of first adambulacral of adjacent series. Segmental apertures are small. Aperture papillæ small, "jawbone-shaped," articulated by broader end, and free on aboral margin.

Mouth plates, with a broad, free margin. Marginal spines 6 or 7, the innermost tapering, exceeding the interradial dimension of plate in length, and reaching beyond center of actinostome. The next spine is shorter and much slenderer, while the remainder of series rapidly decreases both in length and caliber. The first 4 spines free, but membrane tipped; fifth and sixth usually united by a web. Irregularity exists in that it is occasionally the second and third, or the third and fourth, which are united by membrane. On actinal surface is a robust spine, slightly longer and much stouter than the largest marginal, tapering and pointed, sheathed in membrane, free, and directed outward away from actinostome. In a smaller specimen this spine is relatively larger, club-shaped, transparent, pinkish in color and crystalline in luster.

Actinolateral spines are very slender, rather long, the lateral fringe extending beyond the margin of test. Actinolateral membrane plane, wide.

Color in alcohol, faded pinkish gray to yellowish gray.

Localities: Type (no. 21184, U. S. National Museum) from station 3867, Pailolo Channel, between Maui and Molokai islands, 284-290 fathoms, fine sand and mud; bottom temperature, 43.8-44°; 2 specimens. Taken also by the *Albatross* in 1891, 3472, south coast of Oahu, 295 fathoms, fine white sand; 3476, same locality, 298 fathoms, same bottom; 1 specimen each haul.

This species is characterized by the reticulated supradorsal membrane, by the numerous and prominent spinules of the abactinal paxillæ, which give a very roughened appearance to the surface of the supradorsal membrane, and by the armature of the adambulacral plates and mouth plates. The spines of the mouth plates are not webbed, except 2 very small lateral marginals. The species appears to resemble most nearly *Pteraster semireticulatus* Sladen, from which it differs in the details of the adambulacral spinulation, the armature of the mouth plates, and to a less extent in the details of the dorsal surface.

#### Genus *HYMENASTER* Wyville Thomson.

*Hymenaster* Wyville Thomson, *The Depths of the Sea*, London, 1873, p. 120. Type, *Hymenaster pellucidus* Wyville Thomson.

#### *Hymenaster pentagonalis*, new species.

Pl. XXXVIII, figs. 6, 6a-b; pl. XI, fig. 2; pl. XLI, fig. 1.

Marginal contour nearly pentagonal. No interbranchial arcs in perfect specimen, the sides being fairly straight.  $R=80$  mm.;  $r=60$  mm.  $R=1.33$  r. Abactinal area nearly flat, or probably in life slightly convex when the tissues are fully expanded. Actinal area plane. Margin rather thick and fleshy, irregularly scalloped (probably due to unequal shrinkage).

Supradorsal membrane thick, soft, fleshy, and nearly opaque in alcohol. It is irregularly wrinkled, very probably due to shrinkage in alcohol, and in consistency resembles the bell of a tough jellyfish. Scattered rather widely along the radial areas are a number of prominent, soft, pointed papillae. In the type these are almost wanting, or are at least very short, but in 2 other specimens, which undoubtedly belong to this species, they attain the length of about 8 mm. Their size depends somewhat upon the degree of contraction of the dorsal membrane surrounding them. There are about 30 to 40 to each radius, in the specimen on which they are best developed, and 2 or 3 stand in the interradius near the oscular valves. Each has a very slender paxilla spinelet running its whole length. From the outside these paxilla spinelets are scarcely perceptible, as they are exceedingly delicate. If the actinolateral membrane is carefully removed they may be seen springing from the very rudimentary abactinal membrane or true body wall. Each paxilla consists of a slender, cylindrical, basal portion, the summit of which is slightly enlarged to afford articulation for 4 extremely delicate, long, bristle-like spinelets united by membrane, which enter the supradorsal membrane and radiate widely apart, imbedded in the tissue. Occasionally there are 5 in the larger fascicles on the lateral and proximal portions of the radial areas. It is one of these slender spinelets which is imbedded in the papilla and extends to its tip. Not all the paxillar fascicles have papillae corresponding to them. The paxillae are well-spaced and extend in 2 irregular series along each side of the median radial line, those of the outer series being largest. All diminish in size toward extremity of area. No specialized bands of muscle in the supradorsal membrane. Spiracula microscopic, very inconspicuous and impossible to detect without strong magnification; confined to small, elongated, irregular, or substellate groups, of 25 or even more, which are widely scattered among the papillae. Ocular orifice large. Valves broad, nearly truncate, fan-shaped, all united by a web. Spines slender, numerous (18-19), about 10 or 11 mm. long, springing from a fan-shaped, triangular basal piece, with a curved margin (about 6 mm. wide) for the attachment of spines.

Ambulacral furrow wide (8-12 mm.), narrowing abruptly toward extremity; shallow. Armature consists of 2 slender, tapering, sharp spinules close together in a longitudinal, often a trifle oblique series, on tumid furrow margin. Adoral spinule is slightly the longer, although near base of ray it may be shorter. Both are sheathed in membrane, which is not evident except at tip, where there is a sort of fleshy thickening, extending slightly beyond extremity. Distal plates of series (usually beyond middle) have only 1 spine. Rarely a few scattered plates in proximal portion of series have but 1, also, and the first plate usually 3. Segmental apertures small; aperture papilla (the spinule standing directly in front of each aperture and acting as a valve to close it) of fairly large size, rather broadly suboval, invested with a pulpy membrane. Aperture papilla of the first adambulacral plate is multifid, and is immersed in the actinolateral membrane, for which it acts as a sort of support, immediately behind the combined mouth plates.

Mouth plates large and broad, with a prominent keel at the interradiation junction of the plates. The outer end of the combined pair is most prominent, forming a sharp point which projects upward when the specimen is laid on its back. The inner end also forms a beak pointed toward the actinostome. Armature consists of a marginal series of 5 sharp, slender spinules on the lateral flange. Rarely a sixth spinule is added adjacent to the first adambulacral. A membrane-invested spinelet similar to and homologous with the aperture papillae stands just external to the innermost of the marginal spinelets. Rarely an acicular spinelet stands on the general surface of the lateral flange.

Actinolateral spines long, slender, and rather closely placed, about 40 to 50 in number. Actinolateral membrane translucent.

Madreporic body, as seen through the dorsal osculum, is large and very convex.

Color in life, light rose pink.

Localities: Type (no. 21185, U. S. National Museum) from station 4090, northeast approach to Pailolo Channel, between Maui and Molokai islands, 304-308 fathoms, fine gray sand; bottom temp. 43.8°. Taken also at 3911, south coast of Oahu, 337-334 fathoms, fine gray sand and mud; 3914, 289-292 fathoms, gray sand and mud, same locality (6 specimens).

This species is characterized by the shape of the disk, the generally fleshy character of the supradorsal integument, by the microscopic spiracula, and by the armature of the adambulacral and mouth plates. It most nearly resembles *Ilymenaster carnosus* Sladen, from off the west coast of South America (1,500 fathoms), from which it differs in the number and distribution of spiracula, character of abactinal surface, shape of disk, armature of adambulacral and mouth plates, and probably also in having weaker paxillae spinelets.

Genus *BENTHASTER* Sladen.

*Benthaster* Sladen, Journ. Linn. Soc. London (Zool.), vol. xvi, 1882, p. 242. Type *Benthaster wyville-thomsoni* Sladen.

*Benthaster eritimus*, new species.

Pl. xxxviii, fig. 7: pl. xl, figs. 1, 1a-b.

Marginal contour substellate, interbranchial arcs wide, angular, and only moderately indented.  $R=10.5$  mm.;  $r=6$  mm.  $R=1.75$  r. Rays taper gradually from a broad base, tips upturned. Abactinal surface slightly convex, rather depressed. Actinal surface slightly convex.

Supradorsal membrane is very delicate, appearing scarcely more than a film. It is, however, remarkably resistant, and when examined under the microscope by transmitted, or even reflected light, small muscle fibers can be distinguished meandering through the membrane, forming an illy defined net work. There are, besides, small spiracula (?) scattered here and there. Each appears to be surrounded by a thickening of the membrane, making the aperture well defined when the membrane is examined by transmitted light. But on account of the small size of the animal, these spiracula are quite microscopic, and are impossible to distinguish except in a strong light. It is barely possible that they are apertures through which the spines of the paxillæ protrude (the spines having been broken), but this is in no wise probable from their numbers and position. There is not more than 1 to an indefinite mesh of the muscular reticulum, but they do not occur in all the meshes. The membrane can scarcely be called spongiform, the term used by Sladen in describing *B. wyville-thomsoni* and *B. penicillatus*, for it is thin and of uniform thickness throughout. Paxillæ are fairly numerous and are well spaced. Pedicels are long (for genus), slender, and delicate, springing from delicate cruciform plates with long processes. Pedicels on disk (1.75 mm. long) are about one-half the length of spinelets. The latter are relatively long, delicate, glassy, about 8 to 10 to each paxilla of disk, and about 5 on outer part of ray. They are swollen slightly at base for articulation to tip of pedicel, radiate slightly apart, and protrude for the greater part of their length beyond the supradorsal membrane. Each spinelet appears to be perforated along its entire length by minute holes, and to be made up of 3 rods coalesced, so that a cross-section would appear trilobate.

Cruciform plates, from which the pedicels spring, have remarkably long, slender processes, which are usually unequal. There is no tendency for them to become rotund or squamiform. Ocular orifice is large. The "valves" are large, radial in position, the pedicel much enlarged, and expanded at the top as in *Hymenaster*. A muscle band joins the crests of the pedicels as a sort of sphincter. Spinelets many, arranged on the expanded top of the valve pedicel in about 3 series. Papulæ are large, full, bilobate or trilobate, pulpy sacs, constricted at the base, few in number, and are situated on either side of the ray near the base. Just external to one of the valve ossicles is the small, inconspicuous, madreporic body. Anal opening prominent.

The "superomarginal" plates are reduced to 2, which form an arch over the terminal tentacle and are armed with a tuft of numerous spinelets. They appear to be smaller, or at least to extend not so far orad as in the other 2 species.

Adambulacral furrows are wide. Tube feet large, in 2 series. Armature of adambulacral plates consists of a series of 5, long, slender spinelets, which are invested by an exceedingly delicate membrane. They are placed along the furrow margin, often somewhat obliquely on account of the obliquity of the plate itself. The longest spinelets reach across the furrow. They decrease in length toward the aboral end of the series, the outermost being much shorter than the other 4, which are not greatly different in length. Segmental apertures are apparently absent, but a flattened, short, lanceolate-acuminate spinelet, devoid of any perceptible membrane, stands on the actinal surface of the plate, and is bent outward over the actinolateral membrane. This spinelet is enlarged on the first adambulacral plate, is flat, thin, and irregularly multifid. It is lodged in the actinolateral membrane just external to the mouth plates, and seems to serve as a support for the membrane.

The mouth plates are of the *Hymenaster* type. They are prominent actinally and aborally. Armature as follows: (1) 2 slender spinelets on actinal surface of plate near median suture, the outer slightly farther from the suture than the inner. (2) On the margin near the suture, 2 slender spinelets, the outer of which is about one-half the length of the inner, which stands in a linear series with, and is exactly similar to the innermost actinal spinelet. Two much smaller spinelets stand on a slight lateral flange of the plate and are usually directed into the mouth of the ambulacral furrow. All the spinelets are tapering and sharp, and the larger, at least, are encased in a delicate membrane which is only evident at the tip.

Actinolateral spines rather widely spaced, the fifth or sixth from the mouth plates being longest. They extend beyond edge of body, and there are 18 to each side of a ray. Actinolateral membrane transparent, finely and irregularly marked by fibers, much after the manner of the supradorsal membrane. There is a lateral fringe, which extends a short distance beyond the margin of the body.

Color in alcohol, translucent yellowish gray.

Locality: Station 3824, south coast of Molokai Island, 222-498 fathoms, coral, broken shells; bottom temperature, 49.5°; 1 specimen, type no. 21186, U. S. National Museum.

*Benthaster* is an exceedingly rare type, the other 2 species having been dredged by the *Challenger*. *Benthaster wyville-thomsoni* was taken in 2,900 fathoms in the mid-north Pacific, between Yokohama and San Francisco, near the meridian 170° E., from red clay. *B. penicillatus* came from off the north coast of New Guinea, southwest of the Admiralty Islands, 1,070 fathoms, blue mud. It is somewhat remarkable, therefore, that the present form should have come from not nearly so great a depth.

*Benthaster eritimus* differs in several respects from the 2 other members of the genus. In the first place the nidamental cavity is more spacious, and better developed, as the pedicels of the dorsal paxillæ are rather long, and thus support the supradorsal membrane well above the true abactinal wall of the body. The membrane appears to be plentifully supplied with muscle fibers, which form a sort of reticulum, although they are rather simple in structure. Spiracula are present, especially over the region of the bilobate or trilobate, fleshy "papulæ". These spiracula are said to be absent in the 2 other species. The spinelets of paxillæ are rather fewer in number. Adambulacral armature consists of 5 furrow spines and an aperture papilla. Lateral fringe is present. Marginal plates are much reduced and are confined to the extreme tip of the ray.

## Order FORCIPULATA Perrier.

### Family ZOROASTERIDÆ Sladen, 1889.

Zoroasteridæ Sladen, Report on the Asteroiden collected during the Voyage of H. M. S. *Challenger*, etc., Zool., vol. xxx, 1889, p. 416.

#### Genus ZOROASTER Wyville Thomson.

*Zoroaster* Wyville Thomson, The Depths of the Sea, 1873, p. 154. Type *Zoroaster fulgens* Thomson.

#### *Zoroaster spinulosus*, new species.

Pl. XXIV, fig. 3; pl. XLI, fig. 2; pl. XLII, figs. 5, 6.

Rays 5. R=118 mm.; r=11 mm. R=10.7r. Breadth of ray at base, 12 mm. R=10.6r to 14.3r.

Rays very long and slender, subcylindrical, tapering gradually to a prolonged, finely pointed extremity. Abactinal surface arched, with very evident lateral faces to rays. Edges of furrow tumid. Disk small, slightly tumid, center rather higher than the median ridge of rays. Interbrachial angles extremely acute.

The calcareous skeleton of whole test is composed of roughly diamond-shaped or slightly lobed hexagonal plates, all with rounded corners, arranged in perfectly regular longitudinal and transverse rows. Median radial series is composed of the largest plates of ray, while those of the disk are largest of all. Their arrangement (which is to be regarded as of generic rather than specific importance) is as follows: Surrounding a scalloped, dorsocentral plate are 5 radially situated infrabasals of about the same size. An odd plate may be present between 1 or 2 pairs of these. Outside of infrabasals are the interradially placed, much larger, oblong basals, one of which has the madreporic body at its outer edge. Outside of and alternating with these are 5 primary radials about the same size as the basals. Proceeding outward from each primary radial, along the median line of ray, is a regular longitudinal series of plates, tumid or tuberculated, hexagonal in general form, but with each edge of the hexagon, especially that on either side, indented, giving a shield-shaped appearance. On each side of the radial series is a parallel adradial row of smaller plates which is succeeded by another parallel, somewhat larger series of plates, slightly tumid, and forming a faint ridge at junction of lateral and abactinal faces of ray. The edges of these plates and those of the radial series overlie the adradials. Between this marginal series and the adambulacral plates are 5 additional, perfectly regular, longitudinal series, the plates of which likewise form regular transverse series with the marginals, there being thus 6 plates to each transverse series beyond the adradials. The lower end of the plates of each lateral series,

including the marginal, overlies the upper end of those of the next series below, while the aboral edge of each plate underlies the adoral edge of the succeeding plate in a longitudinal series. At base of ray most of the lateral series are confined to side of ray, only the lowermost taking any part in the actinal surface, but toward the middle of the ray the latter series gradually diminishes in size and ends, and the second series is adjacent to the adambulacrals. In outer third of ray second series dies out, so that then only 3 series intervene between the marginals and adambulacrals. All of the plates are very slightly convex, and the 2 lowermost series are slightly smaller than the 3 upper, all of which are a trifle smaller than the (supero-) marginal series. Papulae are in regular rows between successive series of plates, single, except near base of ray, where there may be 2 or 3 to a pore. Surface of all plates is covered with numerous, delicate, short, papilliform, spinelets, each invested by a thin membranous sheath, which is frequently swollen to resemble a slender miniature barley-grain. These spinelets are articulated to granular protuberances on the surface of plates, and, though numerous, are distinctly spaced. They form a rather coarse nap all over the surface. The medioradial plates are submammilated, and surmounted by a short, stumpy, conical spine. In extreme cases there is a definite carinate ridge along the medioradial line, each plate being surmounted by 1 to 3 short, cylindrical, blunt spines or tubercles. Superomarginal plates are not prominently mammilated as in the *Z. diomedæ* type. In neighborhood of papulae are small, very inconspicuous, forciform pedicellariae scattered among the spinelets. They are larger and more numerous at base of rays and on disk.

The superomarginals, and plates of all intermediate series between them and adambulacrals, each bear a delicate central spinule much longer than the surrounding miliary spinelets. These spinelets diminish in size toward adambulacral furrow. They are usually bent upward, appressed to side of ray, and are articulated to a granular boss on the plate, being surrounded by a number of miliary spinelets and several small pedicellariae.

Each alternate adambulacral plate is developed into a prominent ridge, which extends into furrow, and separates neighboring tube-feet. The other plates do not have such a ridge. Armature consists of 4 rather long, cylindrical, tapering spines, 2 directed into furrow and 2 standing on actinal surface. On distal half of ray the outer spine is much reduced or wanting. The series is disposed in single file along the ridge, and the innermost spinule is rather the most delicate. This is usually directed obliquely and adorally toward center of furrow, and bears at its tip a curious membranous expansion, sometimes subcircular in outline, around the periphery of which are arranged 5 to 8 small forciform pedicellariae, usually graduated in size. These frequently extend down the side of the spinule, the largest pedicellariae being nearest the tip. The second spine is also directed toward center of furrow, but aborally, and bears on its basal portion a giant forciform pedicellaria, often considerably longer than spine itself. Occasionally 2 pedicellariae are borne on the second spine, in which case both are smaller than when there is only one. Again, the third spine has a pedicellaria, but this is not usually the case. On the outer part of each plate 1 or 2 miliary spinelets and a pedicellaria are usually present. This extra spinelet is always much shorter than the 2 actinal spines. The intermediate adambulacral plates bear a mobile, tapering spine on the edge of furrow, about equal in length to the third spine of prominent plates. External to this is a much smaller spinule, which stands in a longitudinal series with outer spinelets of prominent plates, and near its base is a small pedicellaria. Well within the furrow is a small spinelet, just abactinad from the larger, which, except at base of ray, usually bears 1 or 2 small pedicellariae. Occasionally the place of this spinelet may be taken by a single pedicellaria.

Actinostome is deeply depressed, the mouth plates being entirely within the cavity. Their armature consists of 3 or 4 robust, slender, slightly flattened spines at each angle. The innermost pedicellariae are very prominent.

Madreporic body small, with few irregular coarse striations; situated just outside a large interradial (basal) plate. Anal opening small, situated just to left of dorsocentral plate. The tube-feet form 4 close-set rows at base of ray; less obviously 4 on distal half. A prominent plate of one side of the furrow is opposite an intermediate of the opposite.

Variations: The most important variation from the type is that of a full-grown specimen which has regularly 5 spines on the prominent adambulacral plates, the third in addition to the second carrying a large pedicellaria. A small spinule in the type forms a fifth member to the series, but only rarely does a pedicellaria occur on the third or inner actinal spine. Another specimen has a very prominent median radial series of mammilated plates, each of which is surrounded by 1 to 3 stumpy spinelets. In this specimen the superomarginal plates are slightly more prominent than is usual, but

each bears a slender spinule, as in the type. The principal dimensions of the 5 specimens are as follows:

*Measurements of specimens of Zoroaster spinulosus.*

Station.	Radius.	Minor radius.	Width of arm at base.	Proportion of r to R.
	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>	
3892....	117	11	12	1:10.7
4007a ..	122	9	10	1:13.5
4007b ..	90	8.5	10	1:10.6
4112....	150	10.5	12	1:14.3
4139....	118	8.5	10	1:13.8

Color in life: Abactinal surface buff; actinal surface orange buff to orange within furrow.

Localities: Type (no. 21187, U. S. National Museum) from station 3892, north coast of Molokai Island, 328-414 fathoms, fine gray sand; bottom temperature, 42.5°. Taken also at 4007, south coast of Kauai Island, 508-557 fathoms, gray sand and foraminifera; 4112, Kaiwi Channel, between Molokai and Oahu islands, 447-433 fathoms, fine sand; 4139, southwest coast of Kauai, 512-339 fathoms, gray sand and rocks; 5 specimens in all.

The rays of this form are much slenderer than in the *Z. diomedæ* group and also longer. The species is particularly characterized by the armature of the adambulacral plates, by the absence of tubercles from the superomarginals, by the presence of 1 slender spinule on each of the superomarginals and on each plate between the latter and the adambulacral series. There are besides numerous pedicellariæ on the general surface of the body, particularly in the neighborhood of the papular pores.

Family HELIASTERIDÆ Viguer, 1878.

Heliasteridæ Viguer, Anatomie du Squelette des Stellérides. <Arch. Zool. Expér. et Génér. t. VII, 1878, p. 111.

Genus HELIASTER Gray.

*Heliaster* Gray, Ann. N. H., ser. 1, vol. VI, 1840, p. 179. Type *Asterias helianthus* Lamarck.

*Heliaster multiradiata* (Gray).

*Asterias (Heliaster) multiradiata* Gray, Ann. N. H., ser. 1, vol. VI, 1840, p. 180.

This species is reported from the Hawaiian Islands (Sladen, Challenger Asteroidea, p. 556), but was not secured by the *Albatross* expedition. I seriously doubt the validity of this record, as the habits of the species are such that it would not easily escape detection.

Family ASTERIIDÆ Gray, 1840, emend.

Asteriidæ Gray, Synopsis of the Genera and Species of the Class Hypostoma (*Asterias* Linnæus). <Ann. N. H., ser. 1, vol. VI, 1840, p. 178.

*Key to Hawaiian species of Asteriidæ.*

a. Abactinal spines arranged in 3 definite longitudinal series, large and isolated, bearing thick wreaths of pedicellariæ. Armature of adambulacral plates consisting of 2 spines.

*Coscinasterias (Distolasterias) euplecta*

aa. Abactinal plating forming a quadrate meshwork. The plates numerous, small, and imbricating by their 4 lobes, leaving open spaces through which protrude the single papulæ. Each plate bears 1 to 3 small spinelets of uniform size and several crossed pedicellariæ. Armature of adambulacral plates consisting of either 1 or 2 spines.....*Hydrasterias verrilli*

Genus COSCINASTERIAS Verrill.

*Coscinasterias* Verrill, Trans. Conn. Acad. vol. I, pt. 2, 1869, p. 249. Type, *C. muricata*=*Asterias calamaria* Gray.

*Stolasterias* Sladen, Challenger Asteroidea, 1889, pp. 563, 583 (subgenus).

The genus is here used not in the very restricted sense of Perrier (Expéd. Travailleur et Talisman. Echinod. 1894, p. 108), but as equivalent to the subgenus *Stolasterias* of Sladen (Challenger Asteroidea, 1889, pp. 563, 583). It thus includes—besides *calamaria*—*tenuispina*, *gemmifera*, *volsellata*, *stichantha*, *eustyla*, *glacialis*, and other similar forms.

*Stolasterias* Sladen (type *Asterias tenuispina* Lamarck) is antedated by *Coscinasterias* Verrill (type *Asterias calamaria* Gray), and hence becomes a synonym of *Coscinasterias* as used in this broader sense.

In 1894 Perrier (op. cit.) divided this group into 3 genera: *Coscinasterias* Verrill (type, *calamaria*), *Polyasterias* Perrier (type, by inference, *tenuispina*), *Stolasterias* Sladen, emended (type, *glacialis*!). In 1896<sup>a</sup> he added another genus, *Distolasterias* (type, *stichantha* Sladen), for the 5- or 6-rayed species, with 2 adambulacral spines to a plate. Since *Asterias tenuispina* had already been made the type of a subgenus, *Polyasterias* is a synonym pure and simple of *Stolasterias* Sladen (s. s.); while *glacialis*, having served as the type of *Marthasterias*<sup>b</sup> Jullien, does not need another name. This renaming of previously named genera has unnecessarily confused this group of species. Whether we have merely a subgenus of *Asterias*, a genus, or four genera is a matter of opinion. In this paper I have taken the middle course, and have regarded Perrier's genera as subgenera of *Coscinasterias*. They will, in this relation, stand as follows:

Genus *Coscinasterias* Verrill, 1869.

Subgenus *Coscinasterias* Verrill, 1869; type, *Asterias calamaria* Gray.

Subgenus *Stolasterias* Sladen 1889, restricted; type, *Asterias tenuispina* Lamarck (= *Polyasterias* of Perrier).

Subgenus *Marthasterias* Jullien, 1878; type, *Asterias glacialis* O. F. Müller, subnomine *M. foliacea* (= *Stolasterias* Perrier nec Sladen).

Subgenus *Distolasterias* Perrier, 1896; type *Asterias (Stolasterias) stichantha* Sladen.

#### Subgenus DISTOLASTERIAS Perrier.

*Distolasterias* Perrier, Rés. Campag. Sci. du Prince du Monaco, fasc. XI, 1896, p. 34.

#### *Coscinasterias (Distolasterias) euplecta*, new species.

Pl. XLI, figs. 4, 4a-c; Pl. XLII, figs. 1-4.

Rays 5. R = 88 mm.; r = 10 mm. R = 8.8 r. Breadth of largest ray at base, 13 mm. Height of ray near base, 14-15 mm.

Rays robust, fairly elongate, tapering to a bluntly pointed extremity; higher than broad, at least in proximal two-thirds. In section each ray would be pentagonal, the broadest face being the actinal. Sides between ventrolateral and superomarginal spines perpendicular. Either side of the abactinal surface slopes upward toward the median radial series of spines. Disk small, lower than the median radial line of rays. Rays appear constricted at base, and are further marked off from the disk by a sort of transverse sulcus. Abactinal surface of disk convex. Interbrachial arcs very acute.

The abactinal surface of rays is bounded on either side by a dorsal marginal series of plates, either lateral sloping face of the abactinal area being of greater width than the perpendicular sides of the ray. Every alternate plate of the superomarginal series bears a single robust, rigid, sharp, conical, fairly slender spine, 3 to 4 mm. in length, which is encircled at the base with a prominent cushion or wreath of closely packed pedicellariæ covered with membrane. The median abactinal line of the ray is occupied by a precisely similar longitudinal series of subequal spinules which decrease gradually in length toward the tip of the ray, and are also surrounded at the base by a wreath of pedicellariæ. On the outer part of the ray the wreaths touch in alcoholic specimens, but on the proximal half they are always separated by about 2 mm. In the interval between the median radial and superomarginal series of spinelets there may be from 1 to 7 widely separated, exactly similar but smaller spinules, each with a basal wreath, disposed in a longitudinal series. On one large ray there are none whatever. Papulae large, sac-like, delicate. They extend in a longitudinal series of groups (3 or 4 to 8 in each group) on either side of the median radial series of spines, with another similar series just above each superomarginal row of spines. A very irregular series occurs scattered between these two, but there are but 2 series of papular "pores" to either side of the abactinal area. There is a central spinule on the disk, 2 radial spinules near base of ray, and 1 interradial spinule. There are also 5 irregular groups of papulae between the central and basal plates, and among them are a number of large forciform pedicellariæ. The lateral, perpendicular face of the ray is occupied by a series of papulae in groups of 4 to 6. The general surface of the rays and disk is covered with a thin pulpy and slick but tough membrane, marked by numerous irregular, crosswise anastomosing lines of darker color, which appear to be very small furrows, possibly sensory in function.

<sup>a</sup> Contrib. à l'Étude des Stellérides de l'Atlantique Nord. < Rés. Campag. Sci. du Prince du Monaco, fasc. XI, 1896, p. 34.

<sup>b</sup> *Marthasterias foliacea* Jullien, Bull. Soc. Zool. France, 1878, p. 141. Equivalent to *Asterias glacialis*, according to Sladen and Ludwig.

The rather crowded inferomarginal plates form the border of the plane actinal surface. Each plate bears 2 spines in a diagonal, crosswise series, the outer spine usually the longer. Both are flattened, chisel-shaped, and radiate slightly apart. The outer is as long or a trifle longer than the superomarginal spines, and bears, on the outer side of base, a thick, subglobular cushion of pedicellariæ, which do not in this case form a wreath. Each plate bears also 1 or 2 fairly large, forcificiform pedicellariæ at the base of the spines; the inferomarginal plates form a ventrolateral carination to the ray which extends further ventrad than the adambulacral plates. In a sort of shallow groove between the 2 is a longitudinal series of large, solitary, bag-like pedicellariæ. In the actinal interradial furrow there are 8 to 10 large forcificiform pedicellariæ.

Adambulacral plates are small and crowded. Armature consists of 2 equal, flattened, very slightly tapering, obtusely tipped spinules nearly as long as the inferomarginal spines but much slenderer. The tip is often truncate. Ambulacral furrow crowded with quadriserially arranged tube feet.

Madreporic body large, 3 mm. in diameter, subcircular, situated near margin. Striations fine, radiating.

Color in life, rather pale Naples yellow, the arms broadly barred, and the disk mottled, with rich brown madder. A very young specimen is Naples yellow, cadmium at tips of arms.

Young: Small specimens (R=6 to 23 mm.) which I have considered the young of this species differ considerably from the adult in general appearance. The rays are not so high, and the abactinal and superomarginal spines are reduced to tubercles on the plates. An intermediate series of abactinal tubercles extends about one-third the length of the ray. The pedicellariæ are few in number and are scattered over the abactinal and lateral surfaces. The papule are still single. On the disk there is a pentagonal series of tubercles, the primary radials being largest. Inside this apical area are numerous other thimble-shaped tubercles or spinelets. Inferomarginal spines 2, as in adult. Some specimens with regenerating arms are 6-rayed.

Localities: Type (no. 21188, U. S. National Museum) from station 3885, adult and young, Pailolo channel, between Maui and Molokai islands, 136-148 fathoms, sand and pebbles; bottom temperature 64.8°. Taken also at the following stations:

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
3835.....	South coast of Molokai Island.....	<i>Fathoms.</i> 189-182	Fine brown sand, mud.
3859.....	Pailolo channel.....	138-140	Fine sand and mud.
4045.....	West coast of Hawaii Island.....	138-147	Coral sand, foraminifera.
4062.....	Northeast coast of Hawaii Island.....	88-113	Coral, volcanic sand, shells.
4064.....	do.....	63-107	Do.
4066.....	Aleunihana channel, between Hawaii and Maui islands.....	176-49	Rocky.
4079.....	North coast of Maui Island.....	143-178	Gray sand, foraminifera.
4100.....	Pailolo channel.....	130-151	Coral sand, shells, foraminifera.
4101.....	do.....	143-122	Do.

All these specimens, 31 in number, are immature except those from station 4062.

This species is most nearly related to *Stolasterias eustyla* Sladen from the Tristan da Cunha Group, 100-150 fathoms, from which it differs in having 2 instead of 3 inferomarginal spines, stouter and longer adambulacral spines, and a very much less developed intermediate row of spinules between the superomarginal and medio-radial series. Mr. Sladen states in his description of *eustyla* (Challenger Asteroidea, p. 587) that each superomarginal and, by implication, each carinal plate bears a spine. In the present species it is each alternate plate.

**Genus HYDRASTERIAS Sladen.**

*Hydrasterias* (subgenus of *Asterias*) Sladen, Challenger Asteroidea, 1889, pp. 563, 581. Type *Asterias (Hydrasterias) ophidion* Sladen. *Hydrasterias* Perrier, Exped. Scientif. du Travailleur et du Talisman, Echinodermes, 1894, p. 109.

***Hydrasterias verrilli*, new species.**

Rays 5. R=85 mm.; r=11 mm. R=7.7 r. Breadth of ray at base, 13 mm.; greatest breadth, a little beyond the base 16.5 mm.; breadth about midway between base and extremity, 10 mm.

Rays elongate, rather narrow, inflated near base, thence tapering to the pointed extremity; depressed near base but distally subcylindrical. Interbrachial arcs very acute, the series of adjacent

rays being there pressed together. Disk not elevated above actinal surface of arms, from which it is marked off by a slight constriction.

The abactinal plates are not very regular as to shape, but may be said to be cruciform with short rounded processes, by the tips of which adjacent plates imbricate. The median radial series is most regular, and can be easily distinguished. The other abactinal plates are often rather irregular, and small intermediate ossicles may be interpolated to complete the close mesh work, which forms roundish or irregular papular areas, rather smaller than the plates, and containing each 1 or 2 papulæ. The plates themselves are convex and each bears 1 (less commonly 2 or 3) short, stout, subclavate, bluntly pointed spinelet. The spinulation of the disk and rays is the same. In addition, each plate bears 1-3 spaced, small, broad-tipped, crossed pedicellariæ (see pl. xli, fig. 3b). The jaws when viewed from the broad side are quite spatulate, and broader than is usual in this type of pedicellariæ. Sometimes the pedicellariæ appear to be attached to the membrane of the papular area.

Immediately external to the adambulacral plates is a series of much larger, convex, subcordiform plates, possibly representing the inferomarginals. Each of these bears, in a transverse slightly oblique series, 2 blunt, robust, tapering, often slightly curved spines, much larger than any of the abactinal or lateral spinelets, and rather more robust, though not longer, than the adambulacral spines. Occasionally only one spine is present. At the base of the ray a few plates have an accompanying forciform pedicellaria, 4 or 5 times as large as the ordinary forciform variety, and with rounded denticulate tips to the jaws. The superomarginal plates are strongly cruciform, the longest axis being transverse and somewhat oblique. In addition to the usual spaced pedicellariæ each plate bears a single spinelet, identical in shape, but sometimes a trifle larger than those of the abactinal plates. The whole test is overlaid with a thin skin which invests plates, spines, and pedicellariæ. The spinelets are quite easily broken off. In alcoholic specimens they are movable. In general both spines and pedicellariæ appear numerous.

The adambulacral plates are small, short, and band-like, and each bears a cylindrical, untapered, often subclavate, blunt spinelet. Relatively few of the plates have 2 subequal spinelets, but 1 is the rule. Usually the spinelets are a trifle curved, and some have a curious elbow at the base. Like the rest of the test the adambulacral plates and spinelets are invested with thin membrane. Each mouth plate has a large forciform pedicellaria on the actinostomal border adjacent to the enlarged, clavate, pointed mouth spine. Actinostome small, closed by the two mouth spines of each angle.

Madreporic body small, convex, situated nearer margin than center. Striations are in the form of curved or irregular slits, not continuous lines. Along adcentral border of the body are 6 or 7 spines, belonging to the adjacent (basal?) plate.

Locality: Station 3867, Pailolo Channel, between Molokai and Maui islands, 284 to 290 fathoms, fine sand and mud; bottom temperature, 44°; 1 specimen, type no. 21189, U. S. National Museum.

This is a very distinct, and in one respect, aberrant species of *Hydrasterias*. Both *H. ophidion* and *H. richardi* are diplacanthid, but *H. verrilli* usually has only 1 spine to each adambulacral plate. In general form the present species resembles *ophidion* more than *richardi* (which is probably immature). *Verrilli* differs from *ophidion* in the following respects: *Verrilli* has usually but 1 terete, untapered, adambulacral spine, *ophidion* 2, tapered; *verrilli* has no small forciform pedicellariæ on the furrow margin, *ophidion* has; *verrilli* has 2 relatively large inferomarginal spines, *ophidion* 1 small one; *verrilli* has a number of large proximal inferomarginal forciform pedicellariæ, together with 1 large one on each mouth plate, *ophidion* lacks these. Other differences exist in the form of the abactinal plates, spines, and pedicellariæ, as well as in the relative size of the spines of the disk and rays. The madreporic bodies also are different. *Verrilli* is not especially closely related to *richardi*, from which it differs considerably in general form and in details of armature.

This species is named for Prof. A. E. Verrill, of Yale University.

#### Family BRISINGIDÆ G. O. Sars, 1875.

Brisingidæ, G. O. Sars, On some Remarkable Forms of Animal Life from the Great Deepes off the Norwegian Coast, II.—Researches on the Structure and Affinity of the Genus *Brisinga*, 1875, p. 101.

#### Key to Hawaiian genera of *Brisingidæ*.

- a. Abactinal membrane of disk and basal portion of arms punctured by conspicuous papulæ... ODINIA  
 aa. No papulæ present..... BRISINGA

Genus *ODINIA* Ferrier.

*Odinia* Ferrier, Ann. Sci. Nat. (Zool.), t. XIX, 1885, p. 9.

*Odinia pacifica*, new species.

Pl. XLIII, fig. 1; pl. XLVII, figs. 1, 1a-d.

Rays 17.  $R = 240$  mm.;  $r = 13.5$  mm.  $R = 17.7 r$ , approximately. Breadth of ray at base, 7 mm.; at widest part of genital expansion, from 8 to 16 mm.; midway along ray, about 6 mm. Rays united at base, by marginal plates, for a distance of 7 to 8 mm. from margin of disk.

Rays elongate, slender, fairly narrow at base; often swollen considerably just beyond the base into a prominent ovarial inflation, the tumidity of which is greatest abactinally. In some cases the swelling is nearly absent, but in others it is very prominent, resembling a big gall. The latter is probably artificial, having been produced when the creature was thrust into alcohol. Beyond this portion the ray is very slender and gradually tapering, the ambulacral ridge being clearly visible through the thin abactinal membrane. Ray is roughly equilaterally triangular in section, the corners, of course, being well rounded.

Disk of fair size, circular, with rather high sides, so that abactinal surface, which is slightly concave, is raised above base of rays. Margin rounded. Abactinal surface and sides covered with rather robust, irregular plates, close-set, in the integument. Plates scattered in central portion of disk. Between the plates are large papular pores. Papulae single (one to a pore), large, vermiform, numerous. Plates irregularly convex abactinally, and surmounted by 1 to 3 short, round-tipped, untapered spinelets (0.50-1 mm. long). Scattered among these are numerous minute, crossed pedicellariae. The spinelets are so small that they give scarcely more than a roughened appearance. They are longer on the sides of the disk, but there do not exceed 1 mm. in length. Numerous spinelets bear several of the microscopic pedicellariae on their sides. Genital region, at base of ray, covered with thin membrane under which are various sized, very irregular, small, loosely imbricating plates, which increase in size as they recede from disk, the largest plates being in outer part of genital region. Between the plates issue numerous single and generally distributed papulae. The genital region is crossed by rather irregular bands of small imbricating ossicles, which are more prominent than those just mentioned. These cross ribs are about 5 mm. apart and there are about 6 or 7 of them. They bear a few scattered slender needle-like spinules. On proximal third of the inflatable portion of genital region the bands are usually very irregular or interrupted; the plates are generally less prominent, and spines are few and irregularly distributed, there being none on sides of ray. On the more prominent parts of each rib, in the mid-genital region, are 5 very slender spinules on either side, and 2 or 3 others in the mid-dorsal region shorter than the rest. The 3 lateralmost spinules are much the longest (4 to 5 mm.). All are covered with membrane beset with numerous minute, crossed pedicellariae. (Usually about half the spinules have lost the membrane entirely.) Membrane between the spiniferous ribs closely beset with minute pedicellariae like those of disk and spines: These, in fact, extend the whole length of ray, and upon the adambulacral plates. Beyond, or distally from the genital region, the abactinal surface of ray is covered with thin translucent membrane beset with very numerous, scattered microscopic, cross pedicellariae, which often show a tendency to collect in irregular clusters or bunches. The transverse ribs of the genital region are here represented by prominent lateral keel-like ridges, consisting of 5 plates fused together. The missing dorsal portion between two ridges of either side, i. e., that portion which would complete the transverse rib, is reduced to an indistinct line of rudimentary plates, only visible when the membrane is quite dry. The lateral ridges are often not exactly opposite on 2 sides of a ray. They are 5 or 6 mm. apart. Just beyond ovarial region, each bears 5 lateral spines, which are quickly reduced to 4, and on outer half of ray there are but 3. The outer spine, that next to adambulacral plate, is usually longest (8 to 9 mm.), the other two nearly as long. The fourth or fifth when present is considerably shorter. These spines are thickly invested with a membranous sheath, the end of which is often expanded into a flap. Rays are united at their base by lateral and adambulacral plates for about 7 or 8 mm. from disk. Beyond interbrachial angle the lateral or marginal plates may be seen for 15 mm., beyond which point they are only evident at the bases of the ribs and lateral ridges.

Adambulacral plates fairly prominent, forming a rounded margin to the wide furrow. Viewed from the actinal side they are broader than long (length 1 mm. approximately). At base of ray height of plate as seen from side is about 2 mm. Interspaces or sutures between plates broad. Arma-

ture consists of a single large, perpendicular spine, which at about the middle of the genital inflation measures 4 to 4.5 mm. in length. Base of spine is cylindrical or very slightly tapering, but the distal half is compressed and the tip truncate, often slightly flaring. Sometimes a groove runs along outer part of spines; or two parallel grooves are present. Less commonly the tip is bifid for a millimeter. Beyond genital inflation the spines rapidly become much slenderer and tapering, the chisel-like character being lost; and on the outer half of ray they are quite delicate and about 2.25 to 2.5 mm. long. The outer side of large spines is covered by membrane, beset with numerous microscopic pedicellariæ, which are also present on outer face of the adambulacral plates. Furrow side of both spines and plates is devoid of pedicellariæ. The smaller spines bear a flap of membrane beset with numerous pedicellariæ.

Actinostome wide, its diameter 15 to 18 mm. (diameter of disks 27 to 30 mm.). Peristomial membrane thin, semitransparent. Mouth plates with lateral process extending across mouth of ambulacral furrow and meeting a similar expansion from the opposite plate, thus roofing over the proximal end of the radial nerve. The two processes, which are at the inner end of their respective plates, sometimes, but not usually, ankylose. A small spinelet is borne on the end of this lateral process. Three other subequal, short, round-tipped mouth spinelets are present on the free (actinostomial) margin of each plate, the inner at a distance nearly equal to its own length from the median sutural line. All bear near the tip a small tuft of minute pedicellariæ attached to an insignificant membrane. On actinal surface at aboral end of plate is a single spinelet similar to but a trifle larger than the marginal spinelets. The furrow margin of each mouth plate is deeply excavated to accommodate the first pair of tube feet.

Madreporic body rather small, subtubercular, situated on the rounded margin of the disk. Striations few, coarse, radiating.

Color in life, yellowish pink.

Localities: Type (no. 21190, U. S. National Museum) from station 3828, south coast of Molokai Island, 319 to 281 fathoms, broken shells and gravel; bottom temperature, 43.8° F. Taken also at station 3992, vicinity of Kauai Island, 528 fathoms (approximately), fine gray sand and mud; bottom temperature, 39.6° F.; 2 specimens in all.

There are four other known species of this genus, all from the Atlantic: *Odinia elegans* Perrier, *O. robusta* Perrier, and *O. semicoronata* Perrier from off the coast of Morocco, and *O. pandina* Sladen from the Farøe Channel. *O. pacifica* is thus the first member of the genus to be taken in the Pacific Ocean. It approaches, most nearly, *O. pandina* and *O. robusta*, but is less spiny than either of these forms, although quite as large. The skeleton of the basal portion of arms and disk is well developed.

The depth given for the second station at which this species was captured is probably too great. The trawl encountered a soft, muddy bottom, and it was estimated that the net was dragged at depths between 500 and 400 fathoms.

#### Genus *BRISINGA* Asbjørnsen.

*Brisinga* Asbjørnsen, Fauna Litt. Norvegiæ, 1856, Andet Hefte, p. 95. Type *Brisinga endecaenemos* Asbjørnsen.

#### Key to Hawaiian species of *Brisinga*.

- a. Adambulacral armature prominent, crowded. Lateral spines stout and long.
  - b. Rays 14. Disk large; annular ridges very numerous, close together; 2 or 3 prominent actinal adambulacral spines.....*panopla*
  - bb. Rays 9. Disk small; annular ridges not so numerous, or close together.....*alberti*
- aa. Adambulacral armature much less crowded.
  - b. Rays 15. Size large; disk large; annular ridges not very numerous, nor close together.....*evermanni*
  - bb. Rays 10. Disk rather small, thin. Rays delicate, spines weak. Annular ridges rather close together, numerous and prominent. Prickles absent from abactinal membrane of rays. *fragilis*

#### *Brisinga panopla*, new species.

Pl. XLIII, fig. 3; pl. XLIV; pl. XLV, fig. 3; pl. XLVII, figs. 2, 2a-f.

Rays 14.  $R = 235$  mm., approximately;  $r = 13$  mm.  $R = 18 r$  approximately. Depth of disk, 7 mm.; breadth of ray at base, 7 mm.; breadth at widest part of genital inflation, about 10 mm.; at middle of ray, 6 mm.

Rays very long and rather narrow. Genital inflation extensive though not prominent. The genital region extends to about two-fifths or one-half the length of ray. Ray subcylindrical at base, very gradually and but slightly widening along the genital inflation; then even more gradually tapering to the long, very attenuate extremity. Slightly to markedly depressed on basal region; subtriangular beyond genital region, with a broad median ambulacral ridge, due to the collapsing of this abactinal membrane on the ambulacral ridge. Disk large. Lateral arm-spines long and rigid. Disk rather large, subdepressed, but the abactinal surface raised above base of rays, the margin being rounded. Abactinal membrane thin, closely beset with delicate, small, sharp, distinctly spaced prickles about 0.5 mm. in length. Scattered among the prickles are comparatively few microscopic pedicellariæ, together with almost exactly similar but very much larger pedicellariæ. The two distinct sizes are very characteristic of this species, the larger not being found in the three following forms. Interradial plates inconspicuous, with several small tubercles. The abactinal membrane of rays is thin and translucent. The inner part of ray is crossed by numerous (35 to 49) transverse, annular ridges, rather closely placed, which extend 10 to 20 mm. beyond the limits of gonads. These ridges are flexuous and often very irregular. They are placed opposite, or correspond to each adambulacral plate (beyond the eighth), although occasionally a plate will be skipped. Frequently 2 or more neighboring ridges are joined near the radial line, and thence prolonged to the opposite side as a single ridge, corresponding to what would ordinarily be the interspace. The ridges are narrow but prominent, and are composed of many elongated ossicles imbricated end to end, the sutures between which are clearly distinguishable when a ray is dried. Along top of ridge are numerous small, spaced, sharp prickles. The thin membrane investing the ridge is covered with microscopic pedicellariæ. Between the annular ridges the abactinal membrane bears illly defined, transverse bands of minute pedicellariæ, which conform to the course of the adjacent ridges. Among these minute pedicellariæ (which do not form prominent saccular bands) are numerous much larger pedicellariæ, especially abundant on the sides of ray. Near base of ray the integument bears numerous scattered prickles of small size. Beyond genital region abactinal membrane is thickly sprinkled with pedicellariæ, on some rays clustered into well-defined transverse bands. Only the smaller size is present on the outer attenuate portion of the ray.

Ambulacral furrow fairly wide. Adambulacral plates short (2 mm. in middle of genital region, 1.25 mm. at base of ray). They are higher than long in basal half of genital region, but gradually become lower distad. Each ossicle is slightly concave toward the middle, so that the whole series might be roughly likened to the vertebral column of a bony fish. Armature has appearance of being crowded, and can be better understood from the figure than from description. At aboral end of each plate is a slender, delicate spinelet 2 mm. in length, directed across furrow, reaching and often touching its neighbor of opposite side. External to this, on aboral edge of plate, is an oblique transverse series of 2 or 3 spines, 2 on some plates, 3 on others, these two numbers often but not always alternating. When there are 3 spines (4 counting the furrow spinelet) that next to the furrow spinelet (near base of ray, at least) is delicate, about equal in length to the former and likewise directed across furrow, but farther along the ray it becomes larger and upright. This spinule is absent from those plates which have only 2 actinal spines. The next two spines are the same on all the plates. The inner is about 4 to 4.5 mm. long, sharp, slender, and upright. The outermost is fully twice as long (9 mm. in middle of genital region, even 10 mm. on some arms) and the base occupies the greater part of actinal surface of its plate. This spine is sharp, slender, and tapering, and like the others, is invested by a thin membrane extending beyond the tip in a short vermiform flap, the whole length of the spine being closely beset with minute pedicellariæ. The other 2 or 3 actinal spines are crowded at the tips and to a less extent along their length with the larger pedicellariæ also. Near adoral margin of plate in a longitudinal line with the innermost actinal spine (the one which is frequently absent) is a delicate spinelet, shorter than the furrow spinelet, directed upwards or backwards, and like it beset with a cluster of the larger pedicellariæ. Actinal and lateral faces of adambulacral plates covered with scattered pedicellariæ of the two sizes, all of them being very deciduous. As is usual in this family, the spines are characterized by rather prominent longitudinal ridges or flutings, which are especially marked in the largest actinal spines. The series of the latter gradually shortens toward the base of the ray, and at fifteenth adambulacral plate they begin to become truncate. From here they rapidly shorten, while the tip becomes broader and flaring, and is marked by numerous papillæ, while the lateral flutings of the stem end in similar peripheral papillæ on the crown. These spines are not precisely square-tipped, but are cut obliquely so that the summit slopes toward the furrow.

The lateral spines begin at about thirteenth or fourteenth adambulacral plates, and are articulated to lateral plates at the extreme ends of the transverse annular ridges. Consequently the lateral spines are opposite nearly all of the adambulacral plates, to a dorso-lateral process of which they superficially appear to be articulated. Beyond genital region and annular ridges the lateral spines continue as closely spaced for a while, but on the outer third or fourth of ray they are opposite every alternate adambulacral plate, with a few irregularities. Lateral spines are long throughout ray, but longest at about the middle (11-12 mm.). They are covered with membrane beset with minute pedicellariæ. Between the first lateral spine and the disk are about 10 to 12 lateral plates, free from the adjacent adambulacrals, and irregular as to position and shape.

Actinostome large, measuring 18 mm. across. Mouth plates inconspicuous, excavated on the margin toward furrow, and with a lateral prolongation extending into mouth of ambulacral furrow. Armature consists of a delicate spinelet about 1.75 mm. in length situated on margin toward actinostome, and another similar but stouter spinelet on tip of the lateral prolongation and directed across furrow. Both have a thin membranous investment expanded at end and covered with minute pedicellariæ (smaller size.). On actinal surface, near outer end of each plate, is a stout pointed spine about 4 to 5 mm. in length, invested in a membranous sheath which is continued beyond the tip as a long vermiform sacculus covered with microscopic pedicellariæ. The spines of companion plate-stand close together and are directed over actinostome. They are the representatives of the truncate spines of the following adambulacral plates, the first 5 or 6 of these having long saccular prolongations at the tips. At base of large actinal mouth spine are 2 slender spinelets, one (2 mm. in length) being longer than the other. Both are directed across the furrow and bear pedicellariæ.

Madreporic body small, sub-tubercular, situated on the margin of the disk.

Color in life, salmon pink, yellowish in tone; in alcohol, bleached ashy.

Variations: A specimen (one arm) from 4178 has quite definite abactinal saccular cross bands of pedicellariæ, more prominent than in type, beyond the genital region. A specimen from 3828 is remarkable in having a dorso-lateral line of ossicles, on either side of the ray about 4 or 5 mm. above the upper margin of the adambulacral plates, which extends nearly to the extremity of the genital region. This series of ossicles crosses and connects consecutive transverse annular ridges. On one ray these are absent. There is no disk preserved, and the specimen is otherwise badly mutilated, but appears fairly typical except in the character just cited.

Localities: Type (no. 21191, U. S. National Museum) from station 4177, vicinity of Niihau Island, 451-319 fathoms, gray sand and globigerina; bottom temperature 41°. Taken also at station 4178; 319-378 fathoms, coral sand, rocks, and pebbles (same locality); station 3828, south coast of Molokai Island, 319-281 fathoms, broken shells and gravel; station 3992, vicinity of Kauai Island, 528 (approximately) fathoms, fine gray sand and mud; 4 specimens in all.

This species is quite distinct from any other Hawaiian form, and is characterized by the numerous annular ridges of the arms and by the almost entire absence of prickles from the abactinal membrane. The armature of the adambulacral and mouth plates, figured in detail, will also furnish additional characters. As compared with the following species, the disk is much larger, the rays more numerous, the annular ridges more numerous, and practically every detail of armature different, as shown by the accompanying figures. *Brisinga panopla* shows relationship with *B. multicostata* Verrill, and *B. cricophora* Sladen, both from the Atlantic, but differs from these species in the details of its structure.

#### ***Brisinga alberti*, new species.**

Pl. XLV, figs. 1, 2; pl. XLVI, figs. 2, 3; pl. XLVII, fig. 4, 4a; pl. XLVIII, figs. 1, 1a-c.

Rays 9. R=230+mm.; r=11 mm. R=about 23 r. Breadth of ray at base, 6-7 mm.; at widest part of genital inflation, 8.5 mm.; at middle of ray, 5.5 mm.

Rays long and rather narrow, depressed in genital region, which is only very slightly inflated, and which extends about half the total length of ray. Ray gently tapering to an elongate and extremely attenuate extremity. Beyond genital region it is subtriangular in section, with a broad truncate median carination, due to the collapsing of thin abactinal membrane on the ambulacral ridge. Disk small. Lateral spines very long. Disk much smaller than that of *B. panopla*; depressed, the abactinal surface being on a level with base of rays. Abactinal membrane rather thin and densely crowded with small, sharp, tapering, delicate, skin-covered spinelets, 0.75 mm. in length. These are thickest and stoutest in center of disk. Membrane covering plates and spinelets bears scattered microscopic

crossed pedicellariæ. Interradial plate is conspicuous, confined to lateral wall of disk. Abactinal membrane of rays thin and translucent. Basal half of each ray crossed by 25 to 32 transverse, annular ridges, equidistantly placed, and not nearly so close together as in *B. panopla*. These ridges, which begin at the very base of ray, are narrow, prominent, and irregular. They are placed, roughly speaking, opposite alternate adambulacral plates, although there are irregularities in this respect. Occasionally 2 or more neighboring ridges are joined irregularly in the median radial line and variously prolonged to opposite side as a single ridge or as 2 ridges. These annular ridges, as in other members of the genus, are composed of slender ossicles, imbricated end to end, which bear rather widely separated prickles and microscopic pedicellariæ. Membrane between ridges is beset with minute prickles, quite numerous at base of ray, but gradually disappearing until they are practically absent beyond middle of genital region. Besides these, there are transverse bands of microscopic pedicellariæ, more or less interrupted on the median radial line. On outer part of ray, beyond genital region, the pedicellariæ may be scattered, or gathered into more or less definite transverse bands.

Ambulacral furrow fairly wide. Adambulacral plates short and low in genital region (about 2 mm. long). They are longer than high, about as broad as long, and are sharply concave toward the center, as in other species of the genus. Armature recalls that of the preceding species in general features. Furrow spinelets are 2, delicate, slender, the aboral situated on the aboral margin of plate, well within furrow; the adoral, very near but not exactly on the adoral edge, slightly more actinad than the aboral spinelet. Aboral spinelet measures about 2 mm. in length, but on outer part of ray becomes slightly longer. Near base of ray adoral spinelet equals the aboral in length, or is slightly longer (3 mm.), but distad is somewhat shorter. Rarely a second and shorter spinelet is placed just above the adoral, in furrow. All these are sheathed in membrane, which sometimes extends beyond the tip and is covered with microscopic pedicellariæ. On alternate plates (or less often) the aboral furrow spinelet is lacking. Actinal spines 2, in a slightly oblique transverse series along aboral margin of plate in a line with the aboral furrow spinelet (when that is present). In basal portion of some rays there may be 3 actinal adambulacral spines. The inner spine, which is much smaller than outer, measures about 5 mm. in length in mid-genital region. The outer spine, articulated to a slight boss on plate, is slender and needle-like and attains a length of 15 or 16 mm. at outer part of genital region. Both spines are invested in membrane, which is prolonged beyond the tip and is closely crowded with microscopic pedicellariæ. Beyond genital region the adambulacral plates are longer and slenderer. There are usually 2 furrow spines, the aboral the longer, and but 1 actinal spine. On plates adjacent to which there is a long lateral spine (usually alternate plates), this actinal spine (which represents the outer long spine of the basal region of ray) is shorter (about 4-8 mm., according to position); but on alternate plates (between lateral spines) it is very long and slender (9-14 mm., according to position). Eight or 9 of the outer actinal spines at base of rays are peculiarly modified, as in *B. panopla*, *B. cricophora*, and *B. multicosata*. These spines are short (4-8 mm.) and robust, with fluted sides and an expanded, truncate, papillose summit, somewhat resembling a composite flower. They decrease in length toward the actinostome, the first 1 or 2 spines being usually clavate, acute. In the other direction they pass insensibly into the slender pointed variety. Actinal and lateral surfaces of adambulacral plates are covered with scattered pedicellariæ.

Lateral spines begin at about the eighth or tenth adambulacral plate and are articulated to lowermost plate of the annular ridges. These lateral plates are at first free from the adambulacrals, but on the outer half of the rays appear to be firmly fused thereto. At base of ray the lateral spines are about 8 mm. long and gradually increase in length until, in the mid-genital region, they are 15 mm. long. This length is kept up to very near the tip of ray, when they abruptly shorten. Lateral spines are invested with a membranous sheath extending beyond tip in a short vermiform sacculus and closely beset with microscopic pedicellariæ. The rays are united at base by first lateral plate of either ray. These are rather massive and are articulated also, in the direction the disk, to the interradianal plate, which forms an elbow projecting outward slightly in the interradianal angle at a level with the lateral plates. Lateral plates in basal part of genital region few and irregular as to form and arrangement.

Actinostome not so large in proportion to disk as in the preceding species (about 11 mm.). Mouth plates deeply excavated on margin toward furrow (hour-glass shaped). There is the usual prolongation, which is not so pronounced as in some species, extending from inner furrow corner of plate into the mouth of furrow. Spines numerous. Armature as follows: (1) A short, slender spinelet

(1.5-2 mm. long) on margin toward actinostome and near median suture; a similar spinelet on the lateral prolongation, pointed over furrow. Both bear numerous microscopic pedicellariæ. (2) Along actinal face of plate a curved longitudinal row of 4 tapering spines and spinules extending outward from the inner marginal spine. The third from the outer end is longest (4 mm.), and thence they diminish in length toward either end of series. All are invested with membrane and bear the usual microscopic pedicellariæ. Usually these spines stand erect, but occasionally the outermost is directed over the furrow.

Madreporic body circular, subtubercular, 2 mm. in diameter, and situated at the edge of the disk on curvature uniting lateral and abactinal surfaces. It is situated on the upper arm of the interradial plate, which is more prominent than the others, and is covered densely with spinelets like those of remainder of abactinal surface.

Color bleached ashy in alcohol; probably salmon pink or red in life. The writer does not recollect any member of this family taken during the Hawaiian cruise which departed from this tint. No color is recorded for this species, however.

Variations: A specimen from 3992 has, at base of ray, a third furrow spinelet situated just aborally to the usual adoral spinelet, and less commonly there may be a group of 3 in this position. Similarly there may be 2 aboral furrow spinelets, one situated above the other. The aboral spinelet, which is often typically absent on alternate plates, seems very seldom lacking in this specimen. On the outer part of ray the armature is arranged like that of type, although rarely 2 adoral furrow spinelets are present. In other respects this specimen is fairly typical and does not appear to be a different species.

Localities: Type (no. 21192, U. S. National Museum) from station 4177, vicinity of Niihau Island, 451-319 fathoms, gray sand and globigerina; bottom temperature, 41°; 4 specimens. Taken also at station 3992, vicinity of Kauai Island, between 400 and 500 fathoms; fragments.

This species is characterized by its small disk, extensive genital region, with rather widely separated genital costæ; by the very long lateral and actinal adambulacral spines, and by the armature of the adambulacral and mouth plates. It is a constantly 9-rayed form, and presents some resemblances to *B. cricophora* Sladen from 390 fathoms, northwest of St. Thomas, Virgin Islands. It is, however, widely different from this form in its much smaller disk, fewer rays (11 in *cricophora*), and in the details of its armature. While *B. alberti* resembles the preceding species in the more general features of the adambulacral armature, it is at once separable on account of its smaller disk, fewer rays, fewer and more widely separated genital costæ, and numerous other details shown in the accompanying figures.

Named for my father, Dr. Albert K. Fisher.

#### *Brisinga evermanni*, new species.

Pl. XLIII, fig. 2; pl. XLV, fig. 4; pl. XLVII, fig. 3; pl. XLVIII, figs. 2, 2a-c.

Rays 15. R=at least 270 mm. (ray-tip gone); r=15 mm. R=about 18 r. Breadth of ray at base, 6 mm.; at widest part of genital inflation (70 mm. from disk) 8 or 9 mm.; at distal limit of genital region (100 mm. from disk) 6 mm.

Rays long and slender and somewhat contracted at base. Thence they widen quickly but evenly into the slightly inflated genital region, which is depressed when the ray is straight. Genital region maintains a fairly uniform width nearly to its distal limit, when ray gradually and evenly begins to taper toward the long and attenuate extremity. Portion beyond genital region is more or less depressed in its proximal fourth, but is marked by the usual truncate carination of ambulacral ridge on its outer three-fourths. Disk large. Costal ridges of arms rather widely separated. Lateral spines long.

The disk, which is large, has been somewhat mutilated, but its essential characters remain intact. Abactinal surface is raised but slightly above the bases of arms, and is beset with very short, sharp prickles, distinctly spaced but closely set. Each prickle is invested with a thick membranous sheath, so that it appears papilliform. Around bases of prickles are numerous crossed pedicellariæ. Each spinelet is borne on a slight boss of its plate, and near the border of disk where prickles are shorter each of these slight tubercles may bear a group of 2 or 3 prickles. Surrounding anal opening is a compact group of stout, tapering, sharp spinules, the longest 2 mm. in length and all membrane-invested. Some of the papillæ of general surface appear truncate, especially toward center of disk, but the

invested prickle is always sharp. Interradial plates nearly naked, expanded and spatulate at upper end. Below they narrow and bend outward in a slight elbow, expanding a bit on the interbrachial angle to form 2 distinct condyles for the articulation of proximal marginal plate of each adjacent ray. The interrâdial plate is marked by a shallow longitudinal sulcus or occasionally by two lateral sulcuses, and a central low ridge. Abactinal membrane of rays thin and translucent. The basal two-fifths of ray, occupied by genital region, is crossed by 32 to 38, usually about 35, transverse, calcareous annular ridges or costæ. These ridges begin very nearly at the base of the ray, where they are much closer together (1-2 mm.) than over outer two-thirds of genital region (3-7 mm.). Ridges are narrow and prominent, composed of imbricating calcareous rods which appear very firmly ankylosed, although sutures can usually be distinguished. These ossicles bear numerous microscopic pedicellariæ, and a longitudinal row of numerous, distinctly spaced, sharp, prominent prickles, which are absent from the lateral plates adjacent to each alternate adambulacral. A few of the ridges are incomplete and extend only slightly beyond median radial line; but consecutive ridges appear never to join as is commonly the case in the two foregoing species. While often sinuous in the median radial portion, the ridges are fairly regular and spring from a lateral plate adjacent to each alternate adambulacral, which plate bears the lateral spine, and on the outer two-thirds or three-fourths of the ray, appears firmly ankylosed to its neighboring adambulacral plate. The membrane between ridges bears microscopic pedicellariæ, which are arranged in 1 to 4 narrow bands, according to width of interval. These bands are inconspicuous, are parallel with the calcareous ridges, and on some rays are almost entirely absent. Beyond genital region the pedicellariæ are grouped in transverse lateral bars, and in median radial line are scattered. There are a few tegumentary prickles at base of ray, but these do not extend far beyond disk. Consequently, especially in a dried specimen, the integument of arms appears fairly smooth.

Ambulacral groove has the appearance of being rather wide and shallow in the genital region. Adambulacral plates form a rounded margin to furrow; short (2 mm. long) in genital region; about as high as long; conspicuously longer than in *B. panopla*. On distal portion of ray the plates, as is usual, are longer and slenderer, and all are concave in the middle, especially toward furrow. Armature as follows: (1) A slender furrow spinelet, invested with an inconspicuous membranous sheath bearing microscopic pedicellariæ, situated aborally on furrow margin. At base of genital region this spinelet is about 1.5 to 2 mm. long, and seldom exceeds 2 mm. throughout the ray. (2) On the actinal surface of each plate a long slender spine articulated to a slight prominence or tubercle. On alternate plates this spine is often slightly longer, and placed slightly more laterally, a second shorter spinule (3-4 mm.) being present between it and the furrow spinelet. Sometimes this smaller actinal spinule is absent, although the longer spine is nevertheless placed more to the outer side of the plate. Frequently on plates with 2 actinal spines, the single furrow spinelet is absent. The larger actinal spine measures 8 mm. near base of ray, increasing to 13 or 14 mm. at distal limit of the genital region, whence it again gradually becomes shorter toward tip of ray. All spines are sheathed in membrane, covered with pedicellariæ, but the latter do not appear so conspicuous or numerous as in the 2 preceding species. Adambulacral plates of distal half of arm bear but one actinal spine. On a very few rays there is also but one actinal spine on most of the plates of the proximal half of the ray. Some of the actinal spines at base of ray appear to bear a truncate, flaring tip, but these spines are longer and slenderer than in either of the foregoing species. Most of them are broken so that it is impossible to determine how many possess the enlarged tip.

The lateral spines are articulated to the lateral plates, adjacent to about every alternate adambulacral plate or those which have 2 actinal spines. Lateral spines are present beyond tenth adambulacral plate, and thence very rapidly increase in length, so that in mid-genital region they attain 12 or 13 mm., which is increased occasionally to 15 mm. at the distal limit of the costal region. Membrane and pedicellariæ present.

Actinostome very large, 20-21 mm. in diameter. Mouth plates fairly large, deeply excavated on side toward furrow for accommodation of first tube foot. Actinal surface of plate plane. Armature as follows: (1) A short spinelet (1.5 mm. long) situated on the middle of the margin toward actinostome, and a second slightly larger spinelet, on the tip of the lateral prolongation, directed across the mouth of ambulacral furrow. (2) On extreme outer end of plate is a stout tapering actinal spine about 4 or 5 mm. long. One of the spines of two companion plates is sometimes shorter than the other. Except for this single spine the general surface of the mouth plate is smooth. All the spines bear

microscopic pedicellariæ, which are attached to a thin membranous investment often expanded into a flap at tip.

Madreporic body small and sub-tubercular, situated near margin of disk, at inner edge of interradial plate.

Color in alcohol yellowish white; in life very probably salmon-red or pink.

Locality: Type (no. 21193, U. S. National Museum) from station 3992, vicinity of Kauai Island, between 400 and 500 fathoms, fine gray sand and mud, bottom temperature 39.6°; 1 specimen.

This species is characterized by the large disk, 15 rays, well spaced and well developed genital costæ, which are fairly regular and about 35 in number; by the absence of prickles from the integument, except at very base of arms; by the armature of the adambulacral plates and of the mouth plates.

Named for Dr. Barton Warren Evermann.

***Brisinga fragilis*, new species.**

Pl. XLVI, fig. 1; pl. XLVIII, figs. 3, 3a-c.

A constantly 10-rayed species, smaller than any of the preceding *Brisingas*, and with less conspicuous spines. Some of the characters, especially the armature of the adambulacral plates, are subject to considerable variation. The specimens can be divided into about 5 groups, on account of certain small differences which are certainly not specific in character. The group with the largest number of specimens has been considered the typical form, and the others are referred to in the following description as "variation *a*, *b*, *c*, and *d*," merely as a method of systematizing the diagnosis.

R=171 mm.; r=7.5 mm. R=23 r. Breadth of ray at base 4 mm.; at widest part of genital region (40 mm. from disk) 7 mm.; at last annular ridge 4.5 mm.

Rays long and slender, rather more inflated in the genital region (which is often quite depressed) than are those of the preceding species. Rays very narrow at base and loosely articulated to disk. They gradually expand in genital region, the widest part being about one-fourth distance from base to tip. Outer part very gradually tapering to an attenuate extremity. Annular ridges extend about one-half length of ray, and beyond them the integument is exceedingly thin and delicate. Annular ridges narrow and very prominent. Integument of arms devoid of prickles. Disk small. Lateral spine delicate, shorter than in preceding species.

Disk small and depressed, the abactinal surface being about even with base of arms. Integument crowded with small, ill defined, roundish, subtubercular plates, surmounted by one or two spiculiform spinelets, quite small and covered with thin membrane. Around base of each of these spinelets are scattered a few minute pedicellariæ. The plates are more crowded about the eccentric anal opening, the spinelets immediately surrounding which are larger than the rest. Each spinelet appears to end in 2 or 3 minute points. Interradial plate small. Closely united with it are the proximal marginal plates of either adjacent ray, the three plates forming a rude letter Y reversed. The upper, unpaired bar represents the interradial plate, and the diverging arms the marginals, set at a lower level and closely fused with the interradial. The outer ends of the 2 diverging bars form a double condyle for articulation with the second marginal plate of each ray. The three plates appear superficially as one, and their exposed surface is slightly concave and wholly devoid of spinelets.

Abactinal membrane of rays thin and translucent and entirely free from integumentary prickles. Basal half of ray is crossed by from 24 to 28 annular carinations or calcareous ridges, rather thin but prominent. Even in the same specimen there is considerable difference in the number of ridges on the several rays. What might be called primary costæ are usually opposite each alternate adambulacral plate; but on arms with more than the usual number of costæ the ridges may be opposite 2 or 3 consecutive plates, then skip one, and so on. In addition to the 24 to 28 ridges, which extend completely from side to side of ray, there may be an inconspicuous rudimentary ridge between them on the median line, and not reaching the adambulacral plates of either side. These incomplete ridges, which are usually quite short, do not have any regularity of occurrence. On some rays they are totally absent; on others there is one for about every third intercostal space. Occasionally a primary ridge does not extend wholly across the ray, and all are rather irregularly sinuous in the median line. The plates which compose the annular ridges are compressed, and bear along the keel-like summit distinctly spaced, spiculiform spinelets with swollen bases and very sharp points. There are numerous microscopic pedicellariæ, also, along sides of these ossicles. Membrane between ridges bears one or two narrow transverse bands of microscopic pedicellariæ. These bands are continued beyond the

costal region, one opposite each adambulacral plate, throughout ray. Variation *d*: One specimen from station 4131 has more numerous annular ridges, 35 to 40. The difference is solely due to the greater number and prominence of the secondary ridges, which practically occur in each intercostal space, and reach nearly or quite to the adambulacral plates. They differ from the primary ridges in that there is no larger (infero-) marginal plate joining the slender ossicles with the corresponding adambulacral plate. The secondary ridges are therefore never fused with the adambulacral plates, a small free space always intervening. Variations *a* and *b*: Secondary costæ very few and rudimentary. Bands of pedicellariæ in intercostal spaces are prominent and saccular, and the ridges are also invested in a soft membrane covered with minute pedicellariæ. Primary costæ, 18 to 26.

Ambulacral furrow wide and shallow. Adambulacral plates (1.5 to 2 mm. in length) are about twice as long as wide (in the middle) and rather more than twice as long as high (seen from side). Plates constricted in middle, but especially concave on the furrow face. Armature, especially the furrow spinelets, somewhat variable in arrangement and number. The typical form will be first described, and then the several variations. Armature in type and similar specimens is simplest of all. There is but one furrow spinelet situated near the adoral end of the plate, except on the 6 to 12 proximal plates, where an exactly similar spinelet is present on the extreme aboral end. Both spinelets, which are directed across the furrow, are about 1 to 1.25 mm. in length, are invested in a very thin membranous sheath expanded at the tip, and there covered with microscopic pedicellariæ. On the actinal surface, rather nearer to the aboral edge than to the center of the plate, is a delicate and fragile spinule about 4 mm. in length, invested in a delicate membrane on which are microscopic pedicellariæ. This spinule is more delicate than is usual in this genus for the principal adambulacral spine. On account of their extreme fragility, nearly all of these spines are broken in the type series. Variation *a*: On the proximal 12 or 15 plates (basal fifth of ray) there are 2 adoral furrow spinelets, 1 right above and slightly aborally from the other, and 1 aboral spinelet as in the type. Rarely there are 3 adoral spinelets at the very base of the ray. On the next few plates, about the fifteenth to twentieth, the aboral spinelet is missing. On the outer three-fourths of the ray the furrow armature is that of the type—1 adoral spinelet. The actinal spine is a trifle stouter and longer than the other specimens (7 mm. in mid-genital region). (1 specimen, station 3817.) Variation *b*: Resembling *a*; proximal plates with 3 furrow spinelets, 2 adoral and 1 aboral. The succeeding 2 or 3 plates lack the aboral spinelet. Outer half of ray as in type. Actinal spine as in type, not so stout or prominent as in *a*. On some rays the aboral spinelet extends nearly to middle of ray, and the 2 or 3 succeeding plates may have only 1 adoral and 1 aboral spinelet. (2 specimens, stations 3892, 4041.) Variation *c*: This is near the typical form, the only difference being that the plates with 1 adoral and 1 aboral spinelet extend about one-third the length of the ray instead of being confined to its immediate base. (2 specimens, stations 3914, 4096.) Variation *d*: Multicostate form with rather stouter actinal spines than type. Furrow armature is practically the same as type, except that occasionally on basal third of ray there will be 2 instead of 1 adoral spinelet. (1 specimen, station 4131.) If the furrow armature is represented graphically by a common fraction, the numerator standing for the aboral spinelet, and the denominator for the adoral spinelet of each plate, the typical formula would be  $\frac{1}{1}$ . If the ray be represented by a line, the base at the left, then the proportion of plates with each type of armature to the whole ray in the different varieties will be about as follows:

Type:

$$\begin{array}{l} \frac{1}{1} \text{-----} \frac{0}{1} \text{-----} \frac{0}{1} \\ \text{A:} \quad \frac{1}{3} \text{ or } \frac{1}{2} \text{-----} \frac{0}{2} \text{-----} \frac{0}{1} \text{-----} \frac{0}{1} \\ \text{B:} \quad \frac{1}{2} \text{-----} \frac{0}{2} \text{ or } \frac{1}{1} \text{-----} \frac{0}{1} \text{-----} \frac{0}{1} \\ \text{C:} \quad \frac{1}{1} \text{-----} \frac{0}{1} \text{-----} \frac{0}{1} \\ \text{D:} \quad \frac{1}{1} \text{-----} \frac{0}{1} \text{-----} (\text{rarely } \frac{0}{2}) \text{-----} \frac{0}{1} \end{array}$$

Lateral spines are not nearly so prominent as in the preceding species. They begin at about seventh adambulacral plate and are articulated to a lateral plate at the end of each primary annular ridge. At the base of ray the spines are about 3 to 4 mm. long; in mid-genital region 6 to 7 mm., and on outer third of ray 4 to 5 mm., being here slightly longer than the actinal adambulacral spinules. In variations *a* and *b* the lateral spines are longer than in the type, but only slightly. Lateral spines membrane-covered and beset with minute pedicellariæ.

Actinostome rather large, 9 mm. in diameter. Mouth plates fairly prominent, not deeply excavated toward furrow, nor is there a prolongation of the inner furrow corner of plate as is usual in this genus. Each plate has a slightly curved edge toward actinostome, and rises gently toward medium suture, which is conspicuous. Armature as follows: (1) A marginal series of 3 short spinelets on edge toward actinostome. These spinelets are 1.5 mm. long, and the lateralmost is directed across mouth of furrow. If a line is drawn from outer furrow corner to inner suture corner of each plate, it would pass (usually) through the bases of 3 spinelets which stand on the actinal surface, the outermost on the very edge of plate and often directed across the furrow. The innermost of the series stands in center of plate and is stoutest but scarcely longer than marginal spinelets. Median spine of this group, which occasionally stands on the slightly excavated furrow margin, is slender and longer. All spinelets have an exceedingly delicate membranous sheath, beset with comparatively few pedicellariæ. In variation *a* the actinal spinelets form a more transverse than diagonal series.

Madreporic body of fair size, subtubercular, being much larger than interradial plate, just adcentrally to which it is situated. Striations coarse, irregular.

Color in life, coral red to light salmon pink.

Localities: Type (no. 21194, U. S. National Museum) taken from station 3824, south coast of Molokai Island, 222-498 fathoms, coral rocks, broken shells; bottom temperature, 49.5-41.5°. Typical specimens also from the following localities: Stations 3865, 3910, 3920, 4090, 4166.

*Record of localities.*

Station.	Locality.	Depth.	Nature of bottom.
3817.....	South coast of Oahu .....	<i>Fathoms.</i> 320	Coarse lava, coral sand, shells.
3865.....	Northeast approach to Pailolo channel, between Maui and Molokai.	256-283	Fine volcanic sand, rocks.
3892.....	North coast of Molokai .....	328-414	Fine gray sand.
3910.....	South coast of Oahu .....	311-337	Fine gray sand and mud.
3914.....	do.....	289-292	Gray sand and mud.
3920.....	do.....	280-265	Gray sand, broken shells.
4041.....	West coast of Hawaii .....	382-253	Gray mud, foraminifera.
4090.....	Northeast approach to Pailolo channel.....	304-308	Fine gray sand.
4091.....	do.....	308-306	Do.
4096.....	do.....	272-286	Do.
4131.....	Vicinity of Kauai .....	309-287	Do.
4163.....	Vicinity of Bird Island .....	293	Coral sand, rocks, foraminifera.

This is the commonest *Brisinga* in Hawaiian waters, and seems quite distinct from any form heretofore described. It is related more or less closely to *B. exilis* Fisher from off the California coast.

## EXPLANATION OF DESCRIPTIVE TERMS.

The technical terms in starfish descriptions are rather numerous. On account of the large number of new forms in the Hawaiian collections, it has been necessary to give rather thorough descriptions, more especially as certain of the species belong to new and often obscure genera. The following glossary is supplied for students unacquainted with starfishes:

*abactinal*, pertaining to the dorsum or back, as opposed to actinal.

*abactinal area*, usually used in speaking of the abactinal paxillar area of phanerozont species.

*actinal*, ventral, used in speaking of the surface on which the mouth opens.

*actinal intermediate plates*, plates paving the actinal surface, between the inferomarginal and adambulacral plates.

*actinal interradiar areas*, actinal area of disk, paved with actinal intermediate plates.

*actinolateral membrane*, membrane uniting the actinolateral spines. (Pl. XI, fig. 1.)

*actinolateral spines*, in the Pterasteridæ the long spines articulated on the body-frame close to the adambulacral plates which form the lateral or marginal web in *Pteraster*, and support the whole actinal floor in *Hymenaster*. See plate XI, figure 1.

*actinostome*, the opening in the actinal skeleton bounded by the mouth plates and first adambulacral plates.

*adambulacral plates*, plates bordering ambulacral furrow.

*ambulacral furrow*, the V-shaped furrow running the length of the rays, in which are the tube-feet; actinal in position.

*ambulacral plates*, plates roofing the furrow.

*aperture papillæ*, in the Pterasteridæ, papilliform spines opposite the segmental apertures. (Pl. XXXVIII fig. 6, ap. p.)

*bivalved*, see pedicellaria.

*excavate*, see pedicellaria.

*fascioles* or *fasciolar grooves*, grooves between special transverse ridges of the marginal plates, occurring over the suture between plates; usually bordered by specialized spinelets. (Pl. IV, fig. 2, shows several fascioles cleared of spines.)

*foraminate*, see pedicellaria.

*forcipiform*, *forciform*, see pedicellaria.

*furrow*, the ambulacral furrow.

*furrow spines*, used sometimes in referring to the spinelets on the furrow margin of the adambulacral plates.

*inferomarginal plates*, the lower or ventral series of marginal plates, usually very prominent in all the Phanerozontia.

*interbrachial arc* or *angle*, arc between 2 adjacent rays.

*madrepore body*, the more or less prominent calcareous sieve marking the external opening of the water-vascular system, situated in an interradius of the abactinal area.

*marginal plates*, the more or less prominent plates defining the contour of the body in the Phanerozontia; usually discernible in other orders.

*mouth plates*, the modified innermost adambulacral plates.

*osculum* or *oscular orifice*, the large central opening guarded by valves in the supradorsal membrane of the Pterasteridæ.

*papula*, the small vermiform, or occasionally compound, dermal branchiæ which protrude through holes in the skeleton.

*papular*, pertaining to papulae.

*papularium*, specialized papular area of Pontasterinæ.

*paxillæ*, or more correctly *paxilli*, columnar or hour-glass-shaped ossicles, with more or less flaring bases which bear at the summit a group of spinelets, usually small. Of these the marginal series is usually different from the rest, and divergent, so as to cover the intervening spaces between the paxillæ. These grade into uniformly granulated plates by many transitional forms. (See Pl. III, fig. 3a, 3d.)

*pedicellaria*, the curious little pincer-like structure occurring in great numbers on some species of starfishes. In some families they are apparently absent. They may be classified as follows:

a. Sessile: without a special basal piece.

1. Incipient or pseudo-pedicellariæ. The jaws do not spring from a specialized depression or foramen.

1a. Simply a group of opposable spinelets; *spiniform*. (Pl. II, fig. 4, ped.; Pl. IX, fig. 1a.)

1b. The spinelets more or less specialized, and on separate plates, arranged in little combs; *pectinate*. (Pl. X, fig. 3.)

1c. With 2 or 3 specialized jaws. (e. g. *Luidia*, Pl. XVI, fig. 1.)

2. Tong-shaped or alveolar pedicellariæ. The jaws spring from a specialized pit or foramen.

2a. The jaws have no specialized depressions into which they fit when opened. The jaws are higher than wide, usually spatulate (pl. XVI, figs. 3, 4, 4a; pl. XXVI, fig. 1b); *foraminate*.

2b. The jaws are low and wide, with no specialized depression into which they fit when opened. Pedicellariæ are mere slits, or resemble a miniature bivalved shell (pl. XXVI, fig. 5; pl. XXVII, fig. 2a; pl. XXXIII, fig. 1); *bivalved*.

2c. The jaws, when opened, fit into a specialized depression (pl. XXVII, fig. 1; pl. XXXI, figs. 2a, 4a, 4b); *excavate*.

b. Pedunculate. Each pedicellaria consists of a basal piece and 2 jaws.

3. The jaws are attached to end of the basal piece nearest them, i. e., the jaws do not cross near the base (pl. XLI, fig. 2); *forciform* or "*straight*."

4. The 2 jaws cross one another. (Pl. XLI, figs. 3b, 4b; pls. XLVII, XLVIII); *forcipiform* or "*crossed*."

*peristomial membrane*, the membrane surrounding the mouth.

*R* or *major radius*, the distance from center of disk to tip of ray.

*r* or *minor radius*, the corresponding interradial dimension.

*segmental aperture* in Pterasteridæ, small aperture at base of each actinolateral spine and at outer edge of adambulacral plate leading from nidamental cavity to exterior; guarded by the aperture papilla, q. v. (Pl. XXXVIII, fig. 6.)

*spines*, *spinules*, *spinelets*, relative terms purely; the spines being the largest, providing any conspicuous spinous appendages are present.

*spiracula*, small openings in the supradorsal membrane of Pterasteridæ. (Pl. XL, fig. 2.)

*superambulacral plates*, especially well-developed in the Astropectinidæ, are small internal ossicles extending from the ambulacral plates to the corresponding inferomarginal, or sometimes to the intermediate plates when the actinal intermediate areas are extensive. (Pl. II, fig. 5f, sa.)

*superomarginal plates*, the upper or dorsal series of marginal plates defining the contour of the abactinal surface in most Phanerozonia.

*supradorsal membrane*, "the veil-like covering or external independent tissue whereby the dorsal nidamental cavity is formed in the Pterasteridæ. The membrane is supported above the true abactinal surface of the animal by the paxillæ, which consist of a long columnar pedicel surmounted by a crown of fine, more or less elongate spinelets. In the majority of forms belonging to this family, fine muscular fibrous bands extend between the tips of the spinelets and constitute a more or less regular fibrous network; and the general tissue of the supradorsal membrane which fills in the interspaces or meshes, is usually perforated by small contractile pores styled *spiracula* by Sars." Sladen.

*terminal or ocular plate*, the unpaired plate at the tip of the ray.

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## EXPLANATION OF PLATES.

(Except where indicated otherwise, all drawings and photographs were made by the writer.)

## PLATE I.

- Fig. 1. *Astropecten polyacanthus*, abactinal view; enlarged to slightly over 2 diameters.  
 Fig. 2. *Astropecten velitaris*, abactinal view; enlarged to about  $1\frac{1}{2}$  diameters.  
 Fig. 3. *Astropecten pusillulus*, abactinal view,  $\times 2$ .  
 Fig. 4. *Astropecten ctenophorus*, abactinal view,  $\times 2$ .  
 Fig. 5. Same, actinal view.

## PLATE II.

- Fig. 1. *Astropecten polyacanthus*. Fifth inferomarginal plate and neighboring adambulacral plates. The upper adambulacral plate is devoid of spines, while in the lowermost (adoral) the furrow spines are standing perpendicularly,  $\times 8$ . 1a. *Astropecten polyacanthus*. Two paxillæ from the base of ray,  $\times 20$ . 1b. Paxilla from ray, about halfway to tip,  $\times 20$ .  
 Fig. 2. *Astropecten velitaris*. Fifth inferomarginal plate and neighboring adambulacral plates,  $\times 10$ . 2a. Paxillæ from base of ray,  $\times 20$ .  
 Fig. 3. *Astropecten ctenophorus*. First 3 inferomarginal plates and neighboring adambulacral plates,  $\times 10$ . 3a. Paxillæ from near center of disk,  $\times 20$ . 3b. Second, third, and fourth supero- and infero-marginal plates seen from the side,  $\times 10$ . 3c. Tenth adambulacral plate,  $\times 10$ . 3d. Mouth plates; the first adambulacral shown on the right,  $\times 15$ .  
 Fig. 4. *Astropecten pusillulus*. Third, fourth, and fifth inferomarginal plates and adjacent adambulacral plates. a<sup>1</sup>, first actinal series of adambulacral spinelets; a<sup>2</sup>, second series; ped., pedicellarian apparatus,  $\times 10$ . 4a. Mouth plates,  $\times 10$ . 4b. Paxillæ from disk near border of interradial area,  $\times 20$ .  
 Fig. 5. *Astropecten productus*. Sixteenth to eighteenth superomarginal plates, and abactinal end of inferomarginals, showing the large lateral spines,  $\times 5$ ; sup., superomarginal plates. 5a. Paxillæ near base of ray,  $\times 10$ . 5b. Side view of a paxilla from base of ray,  $\times 10$ . 5c. Adambulacral plates from near proximal end of furrow,  $\times 8$ ; mar., inferomarginal plate: 5d. Median furrow spine,  $\times 8$ . 5e. Mouth plates,  $\times 4$ . 5f. Cross section taken at about the middle of ray to show better the relation of plates. ab., abactinal integument; ad., adambulacral plate; am., ambulacral plate; inf., inferomarginal plate; sup., superomarginal plate; sa., superambulacral ossicle.

## PLATE III.

- Fig. 1. *Ctenophoraster hawaiiensis*. Adambulacral plates, actinal intermediate plates, and lower end of sixth inferomarginal,  $\times 8$ ; int. pl., intermediate plate; inf., sixth inferomarginal. The spines have been removed from the median adambulacral plate. 1a. Eighteenth and nineteenth superomarginals, from above, to show the lateral spines on upper end of the inferomarginals,  $\times 8$ . 1b. Tip of an inferomarginal spine, much enlarged. 1c. Diagram of an inferomarginal plate. The circles represent the articulation surface for spines. 1d. Paxillæ, about midway between median radial line and edge of paxillar area, from near base of ray,  $\times 10$ . 1e. Median spine of furrow series (adambulacral),  $\times 8$ .  
 Fig. 2. *Psilasteropsis cingulata*. Madreporic body and neighboring paxillæ,  $\times 10$ . 2a. Adambulacral plates and inferomarginal plates near base of ray,  $\times 7$ . 2b. Paxillæ, edge of interradial area,  $\times 10$ .  
 Fig. 3. *Psilaster attenuatus*. Adambulacral and inferomarginal plates,  $\times 5$ . 3a. Paxillæ from a large specimen, base of ray,  $\times 10$ . 3b. Paxillæ from base of ray, showing usual position of spinelets,  $\times 10$ . 3c. Paxillæ from a form with broader rays, base of ray,  $\times 10$ . 3d. A single paxilla, from the side; large specimen,  $\times 10$ .

## PLATE IV.

- Fig. 1. *Astropecten productus*. Abactinal view of one arm and parts of three others, slightly less than natural size.
- Fig. 2. Same. Actinal view of base of ray, showing mouth plates and inferomarginal armature. The spines have been removed from a few inferomarginal plates to show their shape, and the fasciolar grooves, nearly  $\times 2$ .
- Fig. 3. Same. Abactinal view, showing lateral inferomarginal spines, nearly  $\times 2$ .

## PLATE V.

- Fig. 1. *Ctenophoraster hawaiiensis*. Abactinal surface. Natural size.
- Fig. 2. Same. Actinal surface.

## PLATE VI.

- Fig. 1. *Ctenophoraster hawaiiensis*. A portion of disk and base of rays enlarged to a trifle over 2 diameters.
- Fig. 2. Same. Actinal view. The actinal intermediate plates are cleared of spinelets in one interradius.

## PLATE VII.

- Fig. 1. *Psilasteropsis cingulata*. Side view of an arm, enlarged nearly 2 diameters.
- Fig. 2. Same. Two immature individuals, slightly larger than natural size.
- Fig. 3. Same. Abactinal view of adult, slightly larger than natural size.
- Fig. 4. *Psilaster attenuatus*, slightly larger than natural size.

## PLATE VIII.

- Fig. 1. *Psilaster attenuatus*. Mouth plates and actinal intermediate areas, enlarged to slightly less than 2 diameters.
- Fig. 2. *Psilasteropsis cingulata*. Actinal view, enlarged to slightly less than 2 diameters.
- Fig. 3. *Astropecten callistus*. Actinal view, enlarged to slightly less than 2 diameters.
- Fig. 4. *Tritonaster craspedotus*. Actinal view, enlarged to slightly less than 2 diameters.

## PLATE IX.

- Fig. 1. *Tritonaster craspedotus*. Twelfth to fourteenth marginal plates showing the prominence of the inferomarginal series with their long spines,  $\times 8$ . 1a. Fourth and fifth inferomarginal plates and adjacent adambulacrals,  $\times 10$ . A pedicellarian apparatus is shown on one plate otherwise cleared of actinal spines; *int.* intermediate plates. 1b. Paxillæ from abactinal interradial area,  $\times 20$ . 1c. Side view of a larger interradial abactinal paxilla,  $\times 20$ . 1d. Paxilla from radial line, middle of ray,  $\times 20$ . 1e. Mouth plates, side view, showing particularly position of marginal spines,  $\times 6$ . 1f. Adambulacrals, middle of ray, opposite eleventh inferomarginal,  $\times 10$ . 1g. Mouth plates, actinal aspect,  $\times 8$ . 1h. Marginal plates of outer half of ray, viewed directly from above, to show prominence of inferomarginals;  $\times 2$ . All covering has been removed. 1i. Enlargement of a couple of plates,  $\times 8$ . 1j. Marginal plates from side, showing relative height of the 2 series; *sup.*, superomarginals. 1k. Medium spine of adambulacrals,  $\times 10$ .
- Fig. 2. *Patagiaster nuttingi*. Ninth and tenth adambulacrals and fifth and sixth superomarginal plates,  $\times 10$ . Intermediate plates (*int.*) are shown between the two. 2a. Paxillæ from base of ray,  $\times 10$ .
- Fig. 3. *Dipsacaster nesiotis*. Paxillæ from base of ray showing also the prominent papular pores,  $\times 10$ . 3a. Side view of a paxilla from the abactinal interradial area,  $\times 15$ .
- Fig. 4. *Astropecten callistus*. Ninth and tenth adambulacrals and adjacent inferomarginals,  $\times 10$ . The actinal intermediate plates are seen between the two. 4a. Mouth plates,  $\times 8$ . 4b. Paxillæ from base of ray, at side,  $\times 10$ . 4c. Paxilla from another individual,  $\times 10$ . 4d. Some of its spinelets enlarged.

## PLATE X.

- Fig. 1. *Psilasteropsis cingulata*. Actinal view,  $\times 1.3$ . Drawn by H. R. Johnson.
- Fig. 2. *Dipsacaster nesiotus*. Abactinal view,  $\times 1.3$ . 2a. Fourth and fifth adambulacral plates and one intermediate plate,  $\times 8$ . From one plate the inner actinal series of spinelets has been removed. Drawn by H. R. Johnson. 2b. One of the furrow spines seen from the side.
- Fig. 3. *Cheiraster snyderi*. Mouth plate, first 3 adambulacrals, actinal intermediate plates, and inner edge of first 3 inferomarginals, showing particularly the peculiar pedicellariæ characteristic of the genus,  $\times 8$ .
- Fig. 4. *Cheiraster inops*. Sixth inferomarginal plate and 2 adjacent adambulacral plates,  $\times 10$ .
- Fig. 5. *Cheiraster horridus*. Third and fourth inferomarginal plates and adjacent adambulacrals,  $\times 8$ . 5a. Abactinal surface, radial line, near center of disk,  $\times 10$ .
- Fig. 6. *Pseudarchaster myobrachius*. Fourth inferomarginal plate and adjacent adambulacral plates,  $\times 8$ . 6a. Radial and adradial paxillæ near center of disk,  $\times 10$ .
- Fig. 7. *Pseudarchaster jordani*. Fourth and fifth adambulacral plates and adjacent actinal intermediate plates,  $\times 8$ . 7a. Radial paxillæ,  $\times 10$ .

## PLATE XI.

- Fig. 1. *Tritonaster craspedotus*. Abactinal view,  $\times 2$ .
- Fig. 2. *Astropecten callistus*. Abactinal view,  $\times 2$ .

## PLATE XII.

- Fig. 1. *Dipsacaster nesiotus*. Actinal view, nearly twice natural size.
- Fig. 2. Same. Basal portion of arm and part of disk, nearly  $\times 2$ .
- Fig. 3. *Patagiaster nuttingi*. Actinal view, about  $\times 1.5$ .

## PLATE XIII.

- Fig. 1. *Luidia hystrix*, about five-sixths natural size.
- Fig. 2. Same, young,  $\times 1.3$ .

## PLATE XIV.

- Fig. 1. *Luidia hystrix*, portion of disk and basal part of arms enlarged to 1.75 diameters; abactinal view.
- Fig. 2. Same, actinal surface,  $\times 1.75$ .

## PLATE XV.

- Fig. 1. *Luidia magnifica*. Portion of abactinal surface of arm enlarged to nearly 2 diameters.
- Fig. 2. Same. Abactinal view, slightly less than one-half natural size.
- Fig. 3. Same. Actinal surface of ray near disk. Enlarged to nearly 2 diameters.

## PLATE XVI.

- Fig. 1. *Luidia magnifica*. Adambulacral, intermediate, and inferomarginal plates from proximal fourth of ray,  $\times 5$ . A second adambulacral and adjacent intermediate plates are shown. *ap.*, outer adambulacral pedicellaria; *ip.*, intermediate pedicellaria; *inf. p.*, inferomarginal pedicellaria. 1a. Paxillæ from near base of ray, from the 2 inner regular series,  $\times 10$ . The median radial line is to the left and the spines point aborad. Peculiar compound papulæ are shown in upper left corner, the circle indicating where the pedicels of the paxillæ have been broken off.
- Fig. 2. *Luidia hystrix*. Adambulacral plates in basal fourth of ray,  $\times 8$ . Top of figure is aborad. 2a. Paxillæ from near base of ray, from inner regular row but one,  $\times 10$ .
- Fig. 3. *Mediaster ornatus*. Adambulacral and adjacent actinal intermediate plates,  $\times 10$ . 3a. Paxilla from specimen having prominent abactinal pedicellariæ,  $\times 10$ . 3b. Paxillæ, radial and adradial from near base of ray; type,  $\times 10$ .
- Fig. 4. *Nereidaster bowersi*. Adambulacral and adjacent actinal intermediate plates, near base of ray, showing actinal pedicellariæ,  $\times 8$ . 4a. Radial paxilla, abactinal,  $\times 8$ .
- Fig. 5. *Pentagonaster amophilus*. Radial plates,  $\times 8$ . 5a. Adambulacral plates,  $\times 10$ .
- Fig. 6. *Tosia (Plinthaster) ceramoidea*. Adambulacral plates,  $\times 10$ . 6a. Radial and adradial plates, abactinal, near center of disk,  $\times 10$ .

## PLATE XVII.

- Fig. 1. *Patagiaster nuttingi*. Abactinal surface, slightly less than twice natural size.  
 Fig. 2. *Cheiraster inops*. Do.  
 Fig. 3. *Cheiraster horridus*. Do.  
 Fig. 4. *Nereidaster bowersi*. Abactinal view of ray and a little of interradial portion of disk.  
 Enlarged slightly less than 2 diameters.

## PLATE XVIII.

- Fig. 1. *Cheiraster snyderi*. Abactinal view of type, slightly less than  $\times 2$ .  
 Fig. 2. *Cheiraster horridus*. Actinal view, slightly less than  $\times 2$ .  
 Fig. 3. *Cheiraster snyderi*. Actinal view, slightly less than  $\times 2$ .

## PLATE XIX.

- Fig. 1. *Pseudarchaster myobrachi*. Abactinal surface,  $\times 1.66$ . 1a. Actinal surface,  $\times 1.66$ . 1b. Same, young. Abactinal surface,  $\times 1.8$ . 1c. Same. Actinal view,  $\times 1.8$ .  
 Fig. 2. *Pseudarchaster jordani*. Actinal view,  $\times 1.5$ . 2a. Abactinal view,  $\times 1.33$ .  
 Fig. 3. *Goniodiscides sebæ*. Portion of abactinal surface to show papular areas,  $\times 1.33$ .

## PLATE XX.

- Fig. 1. *Mediaster ornatus*. Abactinal view, slightly less than  $\times 2$ .  
 Fig. 2. Same. Actinal view,  $\times 1.7$ .  
 Fig. 3. *Antheniaster epixanthus*. Portion of actinal surface enlarged about twice to show mouth plates and adambulacral armature. Typical form.

## PLATE XXI.

- Fig. 1. *Nereidaster bowersi*. Actinal view; enlarged about  $\times 1.7$ .  
 Fig. 2. *Tosia (Ceramaster) micropelta*. Actinal view,  $\times 1.85$ .

## PLATE XXII.

- Fig. 1. *Pentagonaster ammophilus*. Abactinal aspect, nearly  $\times 1.5$ .  
 Fig. 2. Same. Actinal view.  
 Fig. 3. *Tosia (Plinthaster) ceramoidea*. Actinal view, slightly larger than natural size.  
 Fig. 4. Same. Abactinal aspect.

## PLATE XXIII.

- Fig. 1. *Astroceramus callimorphus*. Abactinal view,  $\times 1.1$ .  
 Fig. 2. Same. Portion of abactinal surface enlarged to about 2 diameters.  
 Fig. 3. Same. Portion of abactinal surface enlarged. The granuliform appearance of the abactinal plates is due to a bead-like roughness of the plates themselves, not to deciduous granules; but granules surround each plate, and are present on the general surface of the marginal plates.

## PLATE XXIV.

- Fig. 1. *Calliderma spectabilis*. Abactinal aspect of a medium-sized individual, about natural size.  
 Fig. 2. Same. Actinal surface.  
 Fig. 3. *Zorcaster spinulosus*. Abactinal view, about natural size.

## PLATE XXV.

- Fig. 1. *Calliderma spectabilis*. Portion of abactinal surface of same specimen as plate xxiv, figure 1,  $\times 1.83$ .  
 Fig. 2. Same. Portion of abactinal surface at base of ray, showing adambulacral and actinal spines; type, about  $\times 1.8$ .  
 Fig. 3. Same. Region of the actinostome; type, about  $\times 1.8$ .

## PLATE XXVI.

- Fig. 1. *Antheniaster epixanthus*. Abactinal aspect of type, natural size. 1a. Adambulacral plate from proximal portion of series, showing the heavy membrane as it appears in life, the granules beneath being nearly obscured; type,  $\times 8$ . 1b. A dried specimen to show appearance after the membrane has shrunken,  $\times 8$ . This specimen is one of the long-armed forms and possesses a pedicellaria at the adoral side of a number of the plates. (See pl. xxix, fig. 2). 1c. Radial and either adradial row of plates, obscured by integument, about one-third distance from center of disk to tip of ray,  $\times 5$ .
- Fig. 2. *Asterodiscus tuberculosus*. Adambulacral plates. Drawn by O. E. Hyde.  
2a. Dorsal tubercles enlarged. Drawn by O. E. Hyde.
- Fig. 3. *Calliderma spectabilis*. Seventh and eighth adambulacral plates,  $\times 5$ .
- Fig. 4. *Tosia (Ceramaster) micropelta*. Adambulacral plates,  $\times 10$ . Drawn by O. E. Hyde. 4a. Radial abactinal plates,  $\times 12$ . Drawn by O. E. Hyde.
- Fig. 5. *Evoplosoma forcipifera*. Mouth and first 3 adambulacral plates,  $\times 7$ . 5a. Inner mouth spine,  $\times 7$ . 5b, 5c. Spines from actinal surface of adambulacral plates,  $\times 7$ .

## PLATE XXVII.

- Fig. 1. *Calliaster pedicellaris*. Adambulacral plate and adjacent actinal intermediate plates in proximal third of series, showing an open and a closed pedicellaria,  $\times 8$ .
- Fig. 2. *Gilbertaster anacanthus*. Abactinal view,  $\times 2$ . (The outlines of disk inclose fig. 2b.) Drawn by H. R. Johnson. 2a. Three adambulacral plates (about one-third R in position), showing one of the large bivalved pedicellariæ on the furrow margin. 2b: Abactinal plates showing the pedicellariæ and flat granules or ossicles by which the plates are covered,  $\times 7$ . p., papulae. 2c. An actinal interradial area to show pedicellariæ, granules, furrow margin, and mouth plates. Drawn by H. R. Johnson.
- Fig. 3. *Astroceramus callimorphus*. Two adambulacral plates and one actinal intermediate plate, the latter bearing a pedicellaria,  $\times 8$ .
- Fig. 4. *Evoplosoma forcipifera*. Abactinal view,  $\times 1.33$ . (The outlines of disk inclose fig. 4b.) Drawn by H. R. Johnson. 4a. Madreporic body and adjacent plates as they are in life, showing tubercles, vermiform papulae, and the granules covered with a soft membranous sheath;  $\times 5$ . An abactinal pedicellaria is also shown. 4b. Side view of abactinal spines,  $\times 5$ .

## PLATE XXVIII.

- Fig. 1. *Calliaster pedicellaris*. Portion of abactinal surface,  $\times 1.8$ .
- Fig. 2. Same. Actinal surface,  $\times 1.8$ .
- Fig. 3. *Asterodiscus tuberculosus*. Side view of ray to show the 2 series of marginal plates,  $\times 1.8$ .

## PLATE XXIX.

- Fig. 1. *Antheniaster epixanthus*. Long-rayed form, abactinal surface of a dried specimen,  $\times 1.35$ .
- Fig. 2. Same. Actinal surface,  $\times 1.35$ .
- Fig. 3. *Evoplosoma forcipifera*. Actinal surface after specimen had been dried,  $\times 1.83$ .
- Fig. 4. *Linckia diplax*. Actinal view of disk and adjacent portion of rays,  $\times 1.83$ .

## PLATE XXX.

- Fig. 1. *Leiaster callipeplus*. Abactinal view, slightly more than  $\times 1.7$ . 1a. Same. Skin removed to show arrangement of plates. Portion of ray has been opened along dorsal line and spread out.
- Fig. 2. *Ophidiaster rhabdotus*. Abactinal view, slightly larger than natural size.
- Fig. 3. *Ophidiaster triseriatus*. Abactinal view, about  $\times 4.2$ . Photo by N. H. Kent.
- Fig. 4. *Ophidiaster sclerodermus*. Abactinal view, slightly larger than natural size. 4a. Actinal surface showing extensive actinal intermediate areas.

## PLATE XXXI.

- Fig. 1. *Calliaster pedicellaris*. Abactinal view, natural size. Drawn by H. R. Johnson.
- Fig. 2. *Ophidiaster sclerodermus*. Actinal surface showing furrow spines and position of pedicellariæ.  
2a. A pedicellaria from the abactinal surface, much enlarged.

- Fig. 3. *Leiaster callipeplus*. Furrow armature, viewed from furrow.  
 Fig. 4. *Ophidiaster lorioli*. Abactinal surface showing adradial plates and position of pedicellariæ,  $\times 10$ . 4a. One of the abactinal pedicellariæ. 4b. Same, the jaws being closed to show the special depressions for jaws and slight fluting on outer face of latter. 4c. Furrow margin and actinal series of papular pores,  $\times 10$ . 4d. Furrow spinelets as seen from furrow, showing accessory granules, about  $\times 20$ . The right is toward mouth.  
 Fig. 5. *Ophidiaster tenellus*. Radial plates,  $\times 8$ . 5a. Furrow margin in the proximal third of the ray,  $\times 10$ .  
 Fig. 6. *Ophidiaster squameus*. Radial and either adradial series of plates,  $\times 10$ . 6a. Furrow margin and actinal surface, the plates below the papular pores being inferomarginal,  $\times 10$ . 6b. Furrow spinelets viewed from furrow,  $\times 20$ . Mouth is toward the right, accessory granules are shown between the spinelets.  
 Fig. 7. *Ophidiaster triseriatus*. Furrow spines,  $\times 10$ . 7b. Abactinal pedicellaria.  
 Fig. 8. *Ophidiaster rhabdotus*. Furrow spines.  
 Fig. 9. *Linckia diplax*. Furrow spines viewed from furrow; mouth is toward left.

## PLATE XXXII.

- Fig. 1. *Pentaceros hawaiiensis*. Abactinal view of type. Reduced to about 0.7 natural size.  
 Fig. 2. Same. Young specimen showing the incipient lophial spines and the lack of other spines, about  $\times 0.7$ .  
 Fig. 3. Same. View of furrow margin of a large specimen showing a triplicanthid armature to adambulacral plates; 2 and 3, second and third series; (first and second actinal series).  
 Fig. 4. *Asterodiscus tuberculosus*. Abactinal aspect of a young specimen,  $\times 1.8$ .  
 Fig. 5. Same. Actinal surface,  $\times 1.8$ .

## PLATE XXXIII.

- Fig. 1. *Pentaceros hawaiiensis*. Portion of actinal surface of type, enlarged.  
 Fig. 2. *Asterodiscus tuberculosus*. A ray and portion of disk of the type enlarged, showing madreporic body and form of tubercles,  $\times 1.83$ .

## PLATE XXXIV.

- Fig. 1. *Asterodiscus tuberculosus*. Abactinal view of type, three-fourths natural size.  
 Fig. 2. Same. Portion of actinal surface of type,  $\times 1.83$ .  
 Fig. 3. *Pentaceros hawaiiensis*. "Apical region" of type, enlarged. The anal opening is seen near the center, and the madreporic body in the lower left-hand corner.

## PLATE XXXV.

- Fig. 1. *Henricia robusta*. Actinal view of type, enlarged about 1.6 diameters.  
 Fig. 2. Same. Abactinal aspect.  
 Fig. 3. *Henricia pauperrima*. Actinal view of type, enlarged about 1.6 diameters.  
 Fig. 4. Same. Abactinal aspect.

## PLATE XXXVI.

- Fig. 1. *Mithrodia bradleyi*. Abactinal view; slightly over 0.7 natural size.  
 Fig. 2. Same. Abactinal surface of one arm enlarged about  $\times 1.8$ .

## PLATE XXXVII.

- Fig. 1. *Mithrodia bradleyi*. Actinal surface,  $\times 1.83$ .  
 Fig. 2. *Mithrodia*. Actinal surface of a ray of a peculiar specimen, possibly a freak,  $\times 1.83$ .  
 Fig. 3. Same. Abactinal surface of same specimen. Compare with pl. xxxvi, fig. 2.  
 Fig. 4. *Ophidiaster squameus*. Abactinal view, enlarged about 4.6 diameters. Photo by N. H. Kent.

## PLATE XXXVIII.

- Fig. 1. *Anseropoda insignis*. Fourth to eighth adambulacral plates and adjacent actinal intermediate plates,  $\times 8$ . The actinal adambulacral spinelets (*ad. 2*) are shown in 2 different positions, the upper being the more usual. The fans of the actinal plates are just to the left of these. *ad. 1.*, furrow spinelets. *1a.* Abactinal plates, interradial, about 30 mm. from edge of disk, and from radial line.
- Fig. 2. *Henricia robusta*. Adambulacral plates,  $\times 10$ . *2a.* Abactinal surfaces, middle of arm,  $\times 10$ .
- Fig. 3. *Henricia pauperrima*. Abactinal surface near base of ray,  $\times 20$ . *3a.* Seventh and eighth adambulacral plates seen from furrow, showing the 2 furrow spinelets,  $\times 12$ .
- Fig. 4. *Valvaster striatus*. Adambulacral plates, near base of R,  $\times 10$ . *4a.* Marginal plates viewed from the side, showing the very large superomarginal pedicellariæ, and inferomarginal spine,  $\times 10$ .
- Fig. 5. *Pteraster reticulatus*. Adambulacral spines,  $\times 5$ . *ap. p.*, aperture papilla. *5a.* Supradorsal membrane near center of disk.
- Fig. 6. *Hymenaster pentagonalis*. Adambulacral plates,  $\times 8$ . *ap. p.*, aperture papilla. *6a.* Mouth plates,  $\times 3$ . *1st. ap.*, first aperture papilla, imbedded in actinolateral membrane. *6b.* An actinal mouth spine from cotype.
- Fig. 7. *Benthaster eritimus*. Paxillæ much enlarged, and seen from side to show height of pedicels and general surface of supradorsal membrane (dotted line).

## PLATE XXXIX.

- Fig. 1. *Pteraster reticulatus*. Actinal surface of type, enlarged about 1.8 diameters.
- Fig. 2. Same. Abactinal surface, slightly larger than natural size.
- Fig. 3. *Ophidiaster lorioli*. Abactinal surface of type, enlarged about 2.7 diameters. Photo by N. H. Kent.

## PLATE XL.

- Fig. 1. *Benthaster eritimus*. Actinal surface (interradial), showing actinolateral spines, membrane, adambulacral plates and armature, and the mouth plates,  $\times 10$ . The first aperture papilla is multifid and is lodged in the actinolateral membrane; the rest are free and lanceolate-acuminate. The circular bodies showing through the actinolateral membrane are the large bi- or tri-lobed, fleshy glandular papulæ. A number of the adambulacral plates have the furrow spinelets removed. *1a.* A portion of supradorsal membrane much magnified, to show spiracula, muscle fibers, and spines. *1b.* Abactinal aspect of entire animal,  $\times 3$ . The supradorsal membrane is broken open in places.
- Fig. 2. *Hymenaster pentagonalis*. Small portion of supradorsal membrane near radial line showing spiracula and papillæ,  $\times 8$ .
- Fig. 3. *Asthenactis papyraceus*. Plates of side of ray in a dry specimen, a few of the dorsal plates showing above,  $\times 8$ . The fascicles of spinelets have been removed from most of the plates, and the integument has entirely dried up. In life the plates are not superficially visible. *3a.* Actinal surface showing one interradius, adambulacral and mouth plates, and the incipient actinolateral membrane, enlarged about 5.5 times. *1, 2, 3,* first to third adambulacral plates. *4s.* Spines on the fourth adambulacral plate. *3s'.* Spines on process of third plate, but forming a single series with those of fourth (*4s*). *2s'.* Similar spines on process of second plate.

## PLATE XLI.

- Fig. 1. *Hymenaster pentagonalis*. Abactinal view of cotype,  $\times 0.75$ .
- Fig. 2. *Zoroaster spinulosus*. Adambulacral plates,  $\times 10$ .
- Fig. 3. *Hydrasterias verrilli*. Actinal surface, showing furrow margin and actinal spines,  $\times 8$ . *3a.* Radial and either adradial series of plates in a dried specimen,  $\times 6$ . *3b.* Abactinal pedicellaria.
- Fig. 4. *Coscinasterias (Distolasterias) euplecta*. Furrow margin and actinal spines,  $\times 8$ . *4a.* Furrow spines seen from furrow,  $\times 8$ . *4b.* Abactinal pedicellariæ,  $\times 35$ . *4c.* Teeth of same.

## PLATE XLII.

- Fig. 1. *Coscinasterias (Distolasterias) euplecta*. Actinal view of an arm and disk. Type; enlarged nearly 2 diameters.  
 Fig. 2. Same. Abactinal aspect.  
 Fig. 3. Same. Young specimen,  $\times 1.83$ .  
 Fig. 4. Same. View of side of arm of a prepared specimen to show arrangement of plates,  $\times 1.83$ .  
 Fig. 5. *Zoroaster spinulosus*. Actinal aspect of type,  $\times 1.83$ .  
 Fig. 6. Same. View of side of ray to show spinules and radial tubercles,  $\times 1.83$ .

## PLATE XLIII.

- Fig. 1. *Odinia pacifica*. Abactinal view, slightly less than natural size.  
 Fig. 2. *Brisinga evermanni*. Abactinal surface of an arm which has been partially dried, about  $\times 1.8$ .  
 Fig. 3. *Brisinga panopla*. Abactinal aspect of genital region of a ray,  $\times 1.8$ .

## PLATE XLIV.

- Fig. 1. *Brisinga panopla*, slightly reduced.

## PLATE XLV.

- Fig. 1. *Brisinga alberti*, slightly reduced.  
 Fig. 2. Same. View of side of a portion of an arm, enlarged about 1.8 diameters.  
 Fig. 3. *Brisinga panopla*. Portion of ray, side view, to show particularly the actinal adambulacral spines and costal spinelets,  $\times 1.83$ .  
 Fig. 4. *Brisinga evermanni*. Actinal surface of ray. Tube feet have been removed,  $\times 1.83$ .

## PLATE XLVI.

- Fig. 1. *Brisinga fragilis*. Disk and 3 rays. The disk and upper ray belong to "variation a." The lowest ray is the typical form, while the middle belongs to "variation d," in which the secondary costæ, only slightly developed in the typical form, extend across the abactinal surface, but do not fuse with the lateral plates. Enlarged about 1.7 diameters.  
 Fig. 2. *Brisinga alberti*. Actinal surface enlarged, showing the curious actinal adambulacral spines near disk,  $\times 1.83$ .  
 Fig. 3. Same. Abactinal surface,  $\times 1.83$ .

## PLATE XLVII.

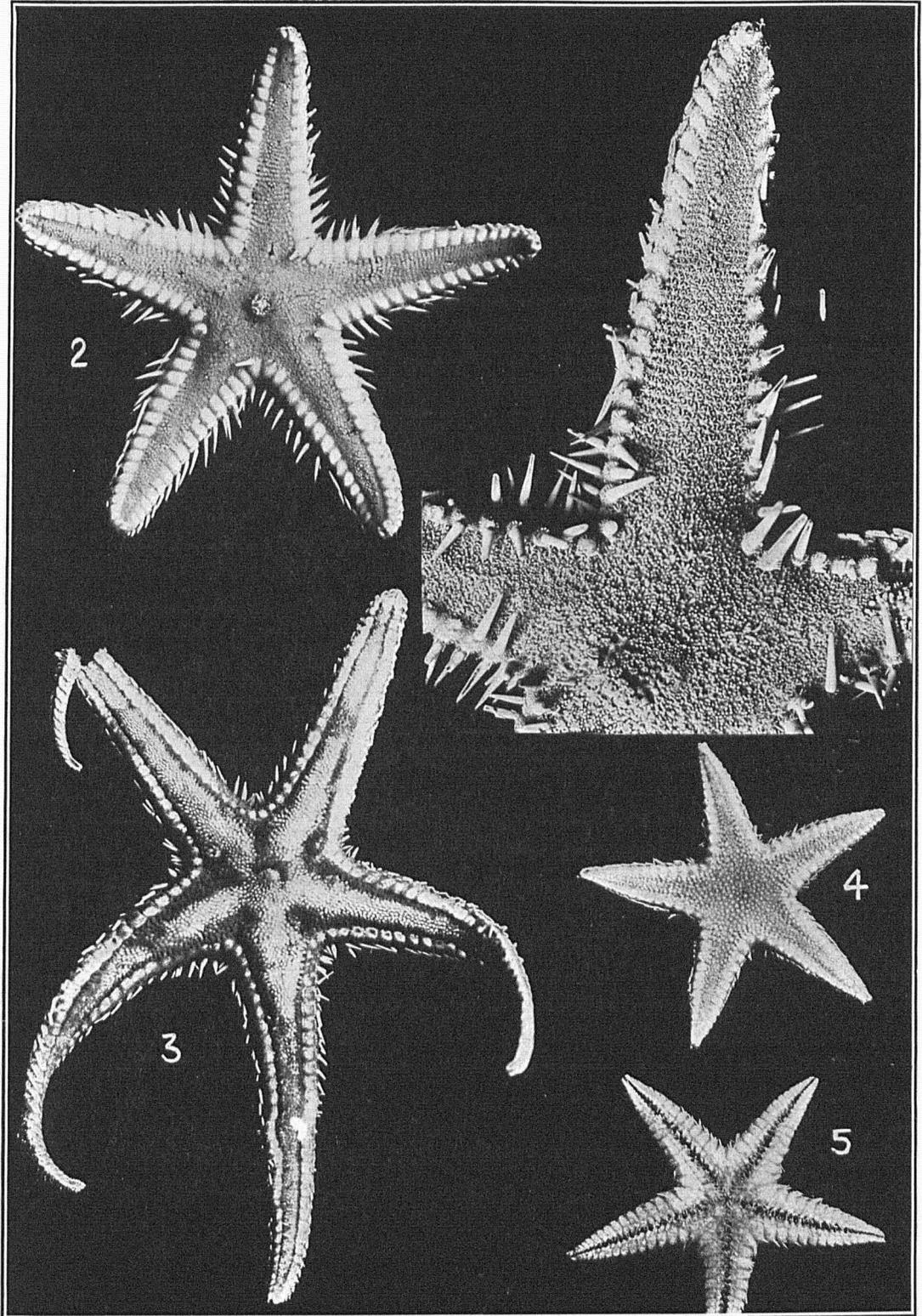
- Fig. 1. *Odinia pacifica*. Side of a portion of ray, mid-genital region, showing actinal adambulacral and first lateral spines,  $\times 2$ . 1a. Same, from a dried specimen,  $\times 3$ . *ad. s.*, adambulacral spines; *ad.*, adambulacral plates; *l. s.*, lateral spines; *c. r.*, costal ridge. 1b. Side of ray, beyond middle, showing lateral spines,  $\times 3$ . 1c. Mouth plates,  $\times 4$ . The lateral process on the right is fused with that of the other side of furrow. 1d. Pedicellaria from adambulacral spine.  
 Fig. 2. *Brisinga panopla*. Side of ray, about 40 mm. from disk, or just beyond the club-shaped actinal spines,  $\times 3$ . Lateral spines, fore-shortened. 2a. Adambulacral plates about 40 mm. from disk,  $\times 4$ . Many of the spines are shown without pedicellariæ. 2b. Adambulacral plates at about 65 mm. from tip of arm,  $\times 4$ . 2c. Mouth plates,  $\times 5$ . *ad. s.*, first adambulacral spines; *am. f.*, ambulacral furrow; *m. s.*, marginal spines; *m. s.'*, furrow spines of mouth plates; *ms.*, actinal spine; *sac.*, sacculus bearing pedicellariæ (see 2d). 2d. One of the larger pedicellariæ from a large adambulacral spine. 2e. Twelfth adambulacral spine,  $\times 7$ . 2f. Seventh adambulacral spine,  $\times 7$ .  
 Fig. 3. *Brisinga evermanni*. Side of ray, about 44 mm. from disk,  $\times 7$ .  
 Fig. 4. *Brisinga alberti*. Side of ray, about 40 mm. from disk,  $\times 3$ . 4a. Pedicellaria from adambulacral spine near base of ray.

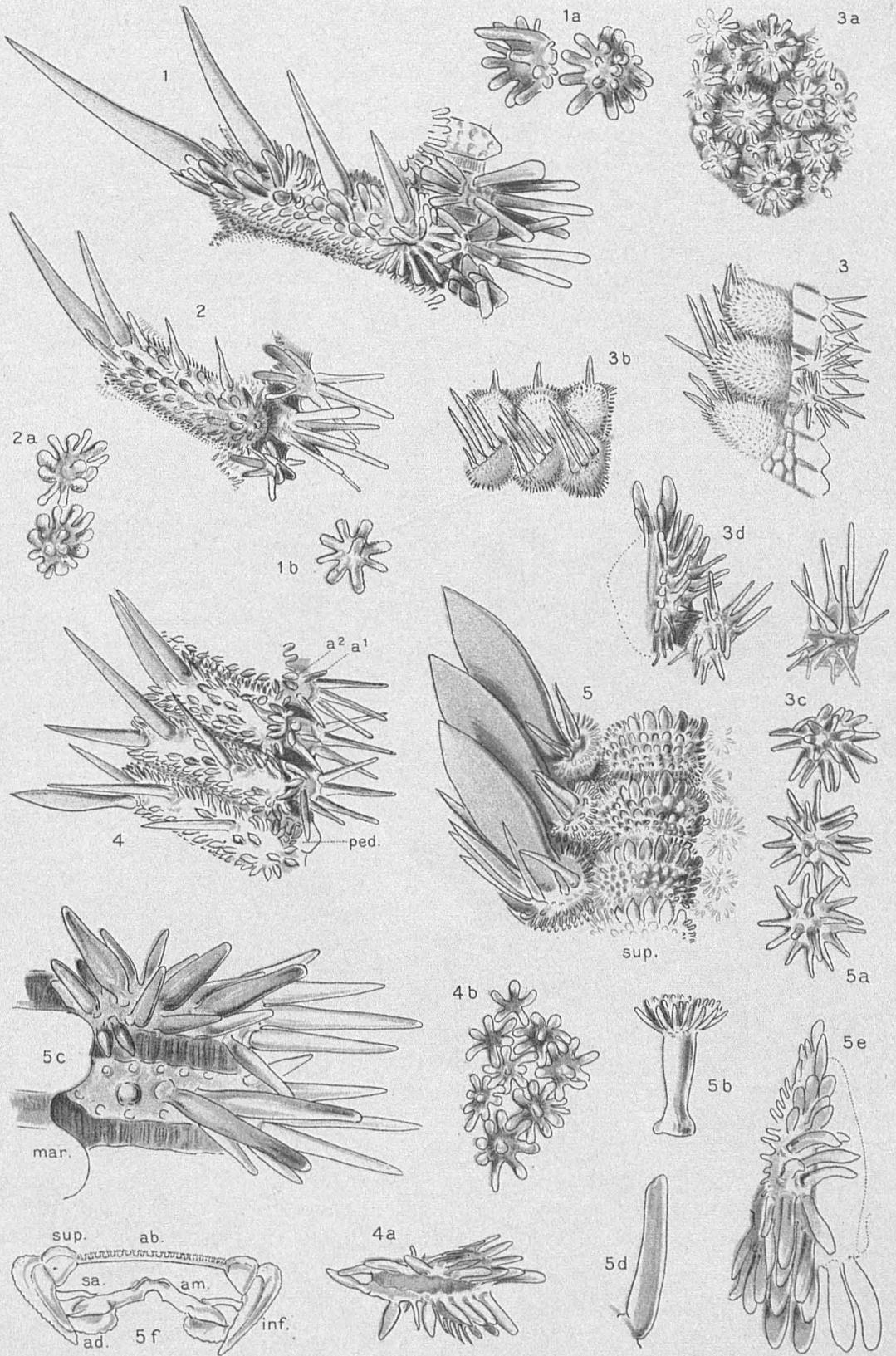
## PLATE XLVIII.

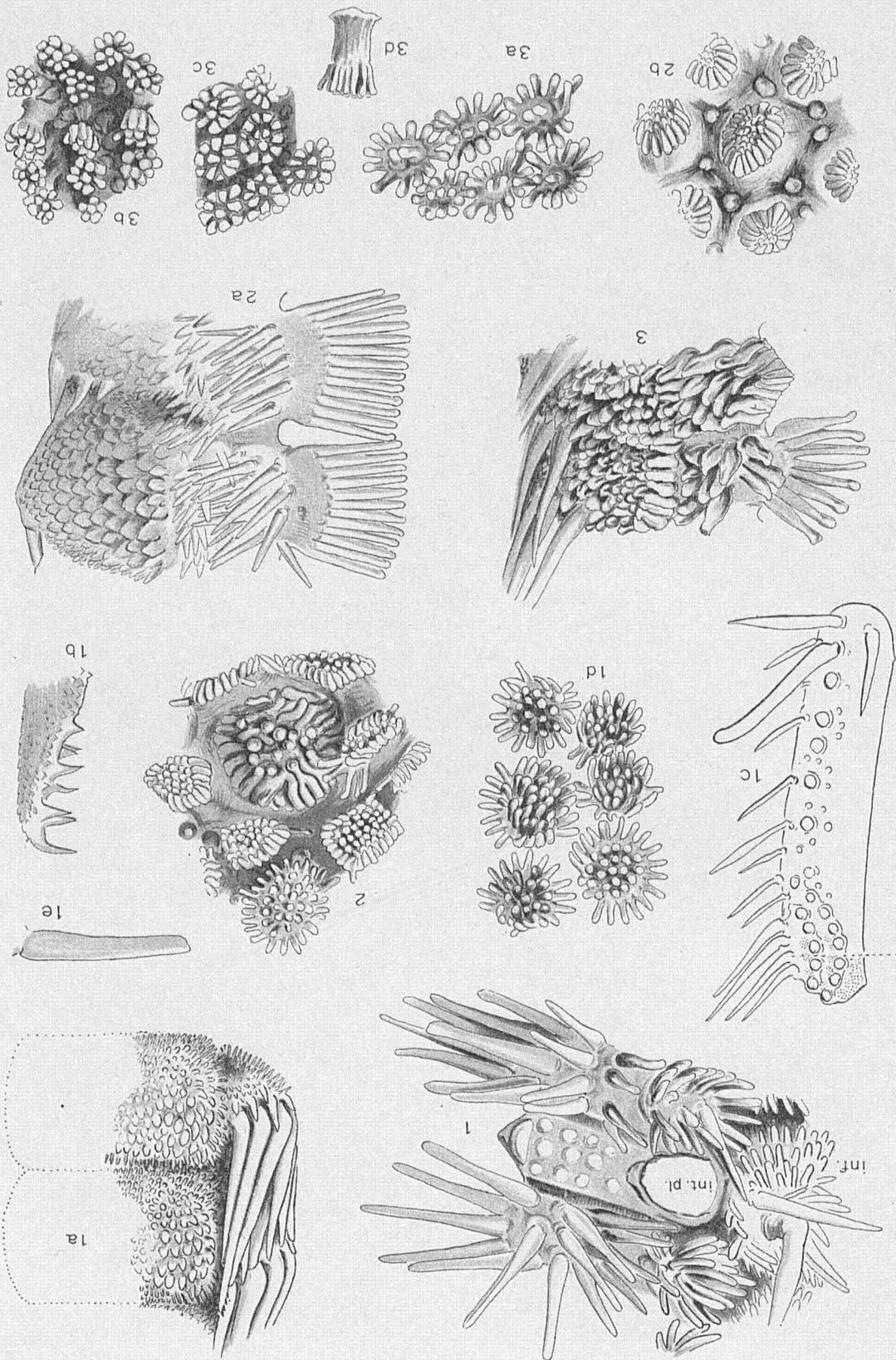
- Fig. 1. *Brisinga alberti*. Adambulacral plates and armature, 50 mm. from disk, showing also the lateral spines (*l. s.*),  $\times 4$ . Lower spines without membrane. 1a. Same, from outer third of arm,  $\times 4$ . 1b. Mouth plates,  $\times 5$ . The first adambulacral is also shown. 1c. Sixth adambulacral spine,  $+ 7$ .
- Fig. 2. *Brisinga evermanni*. Adambulacral plates, 65 mm. from disk,  $\times 4$ . 2a. Same from outer third of ray,  $\times 4$ . The plates should be a trifle slenderer. 2b. Mouth plates,  $\times 5$ . First adambulacrals are also shown in center. 2c. Pedicellaria from adambulacral spine.
- Fig. 3. *Brisinga fragilis*. Side of ray, 35 mm. from disk,  $\times 4$ . 3a. Mouth plates and first adambulacral plates,  $\times 5$ . The single plate to the left represents "variation a," those in center the type, and that on right "variation d," which has a very thick sacculus on the marginal spines. 3b. Adambulacral plates, 50 mm. from disk,  $\times 5$ . 3c. Pedicellaria from one of the long adambulacral spines.

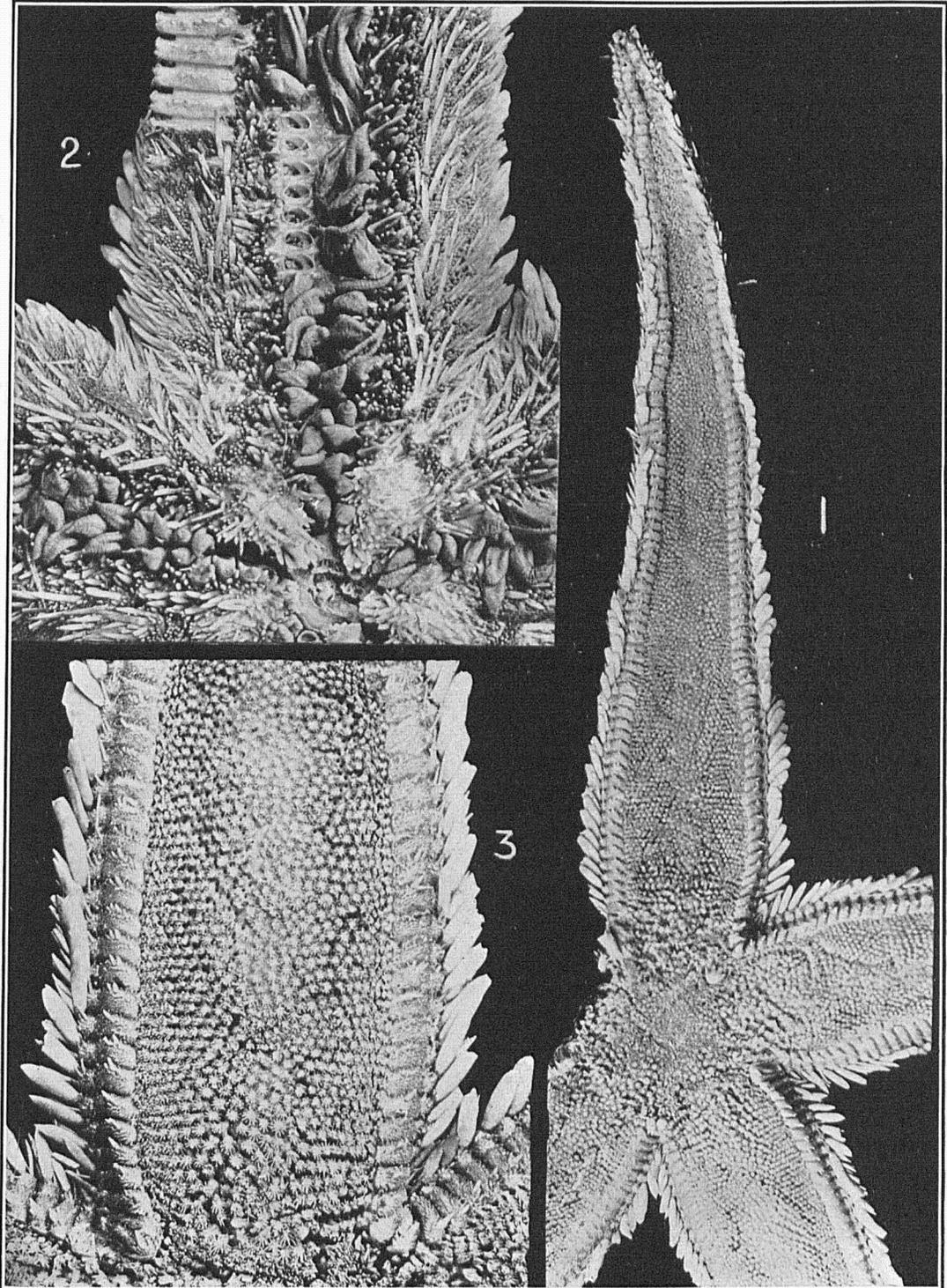
## PLATE XLIX.

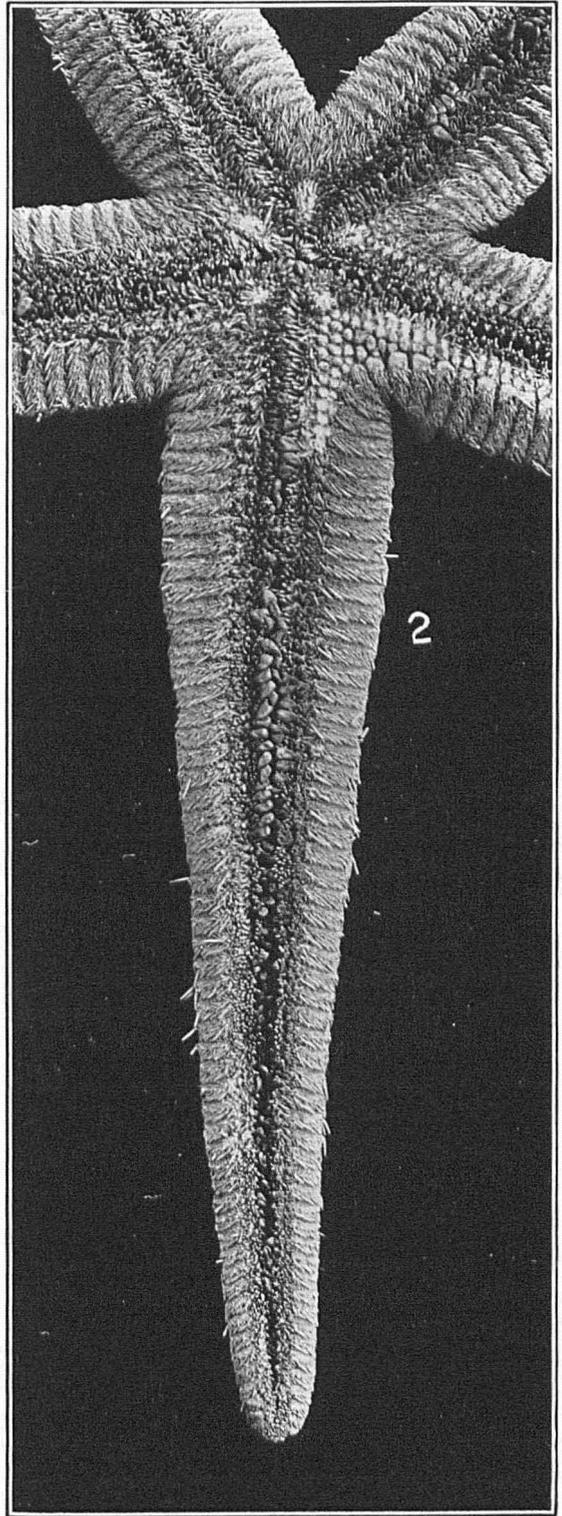
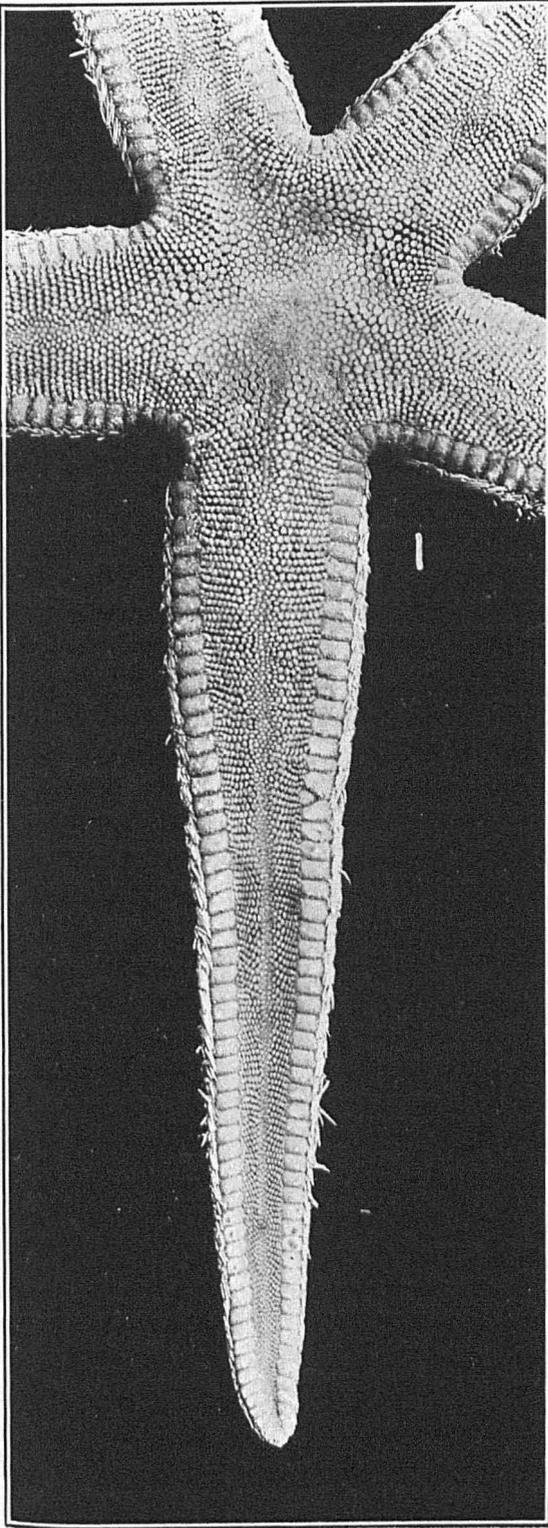
- Fig. 1. *Antheniaster epixanthus*. Abactinal view of short-rayed specimen. Note two parasitic gastropods, one near madreporic body.
- Figs. 2 and 3. *Psilaster attenuatus*, showing growth stages. 2. Thick-rayed form from south coast of Oahu. 3. Typical form.

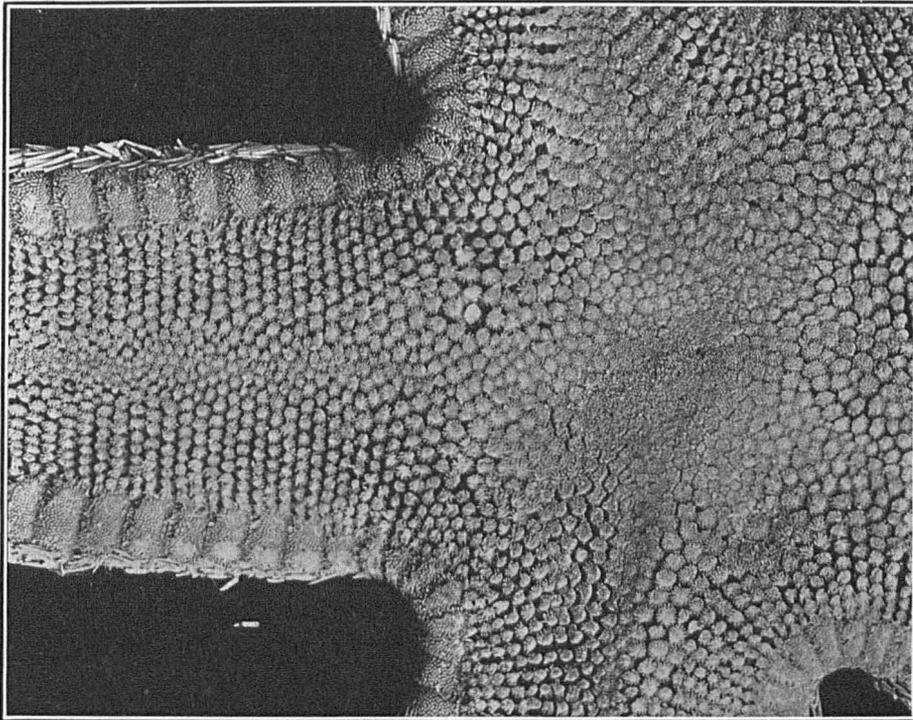
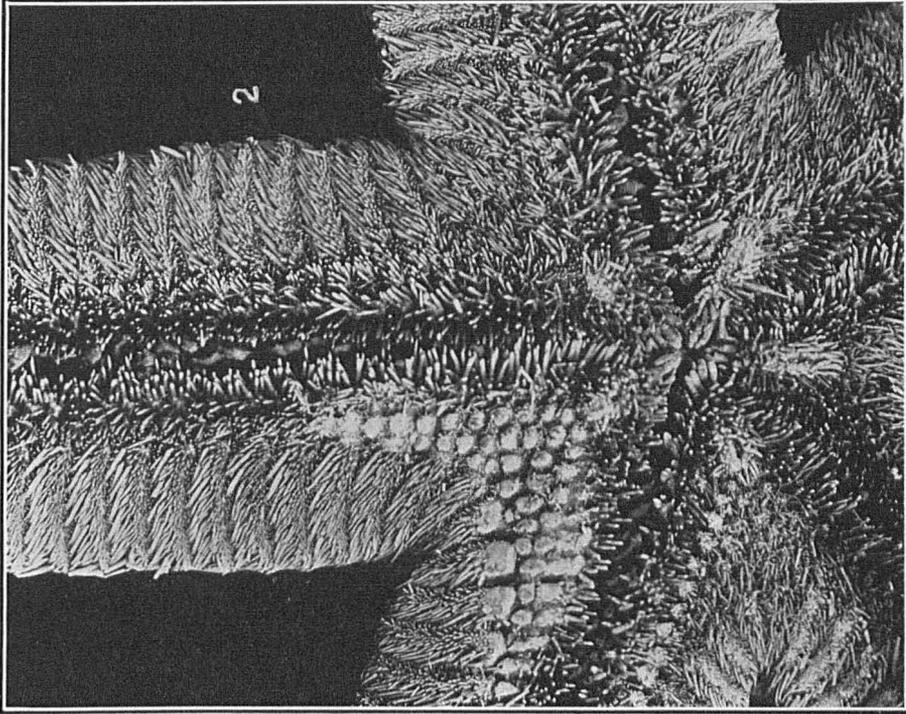


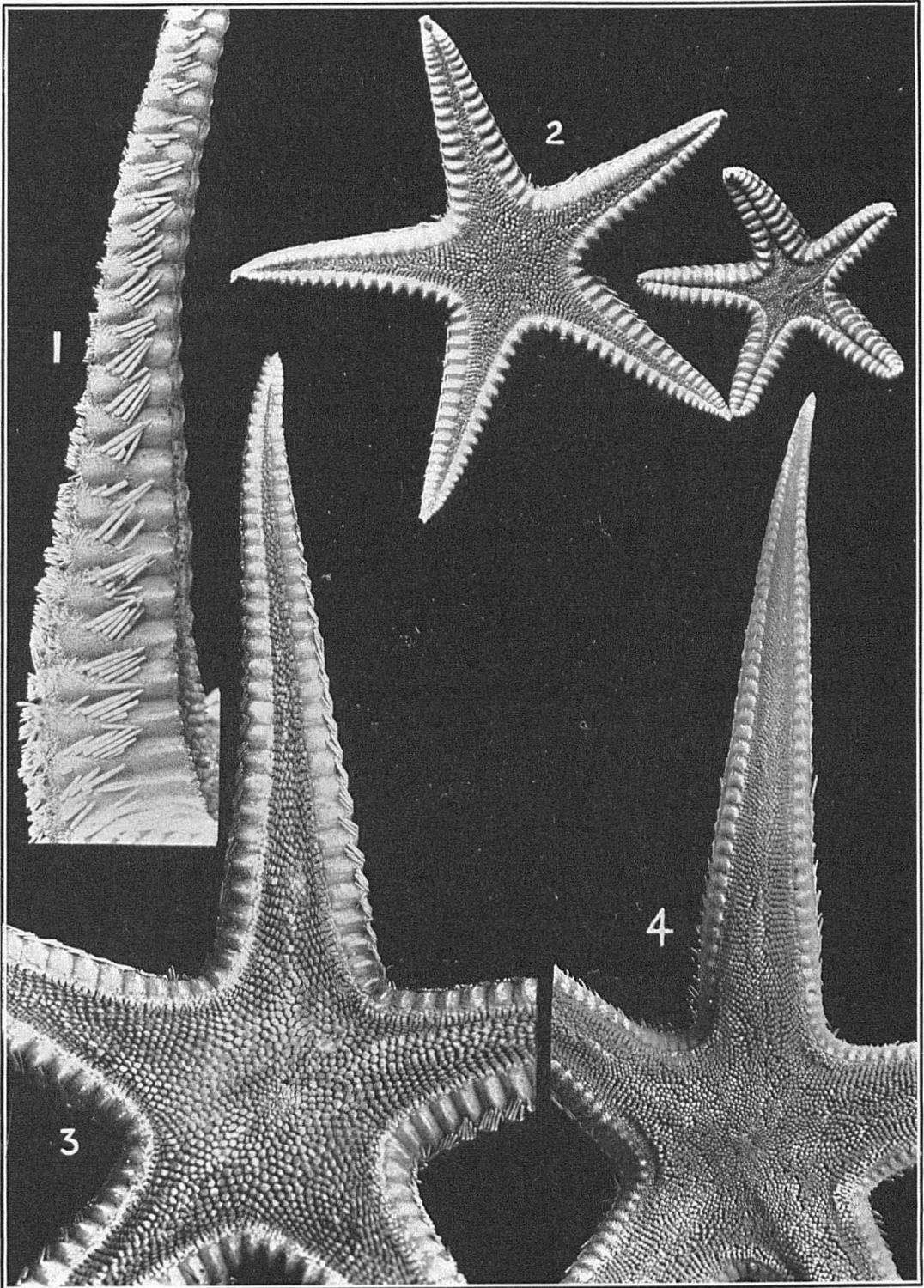


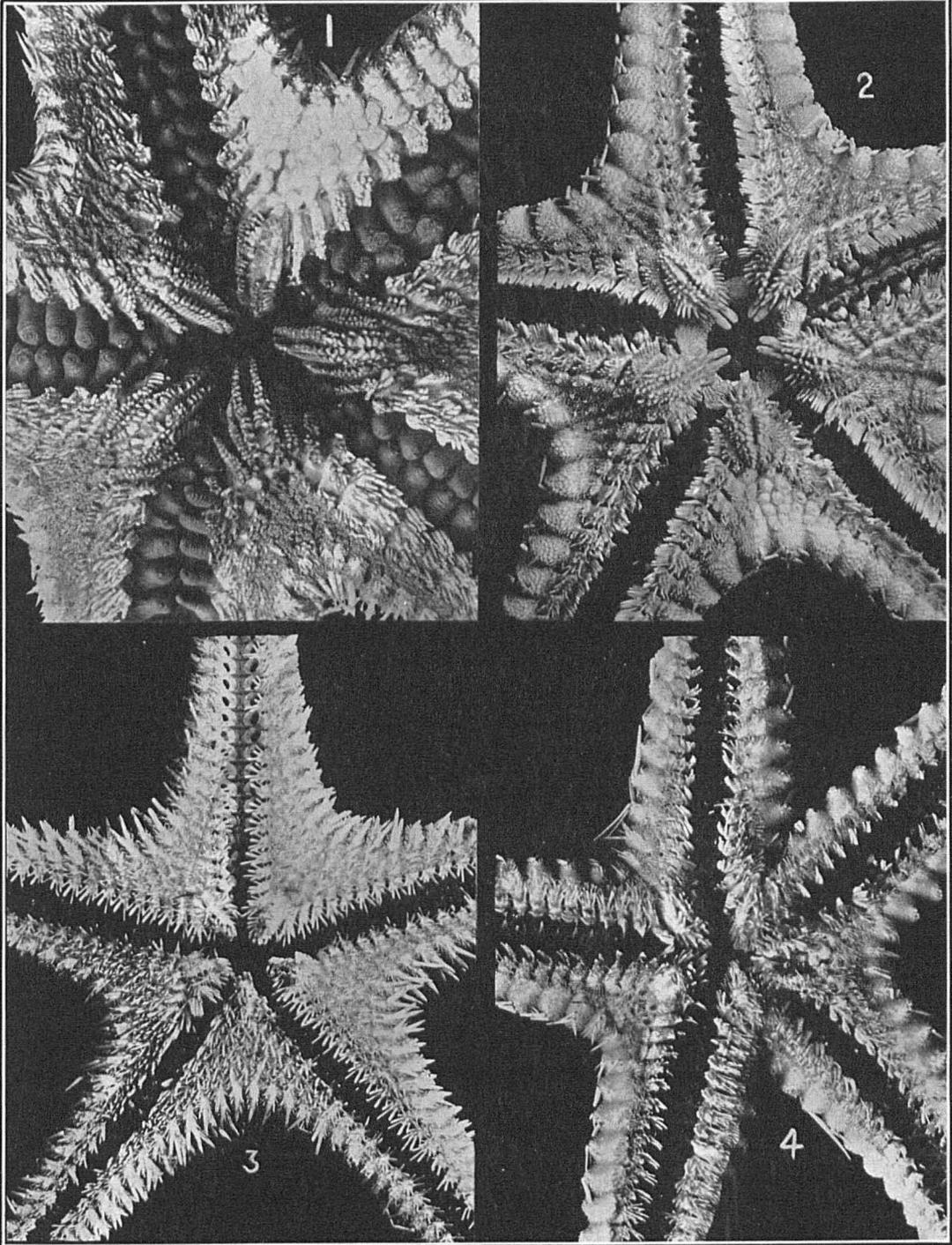


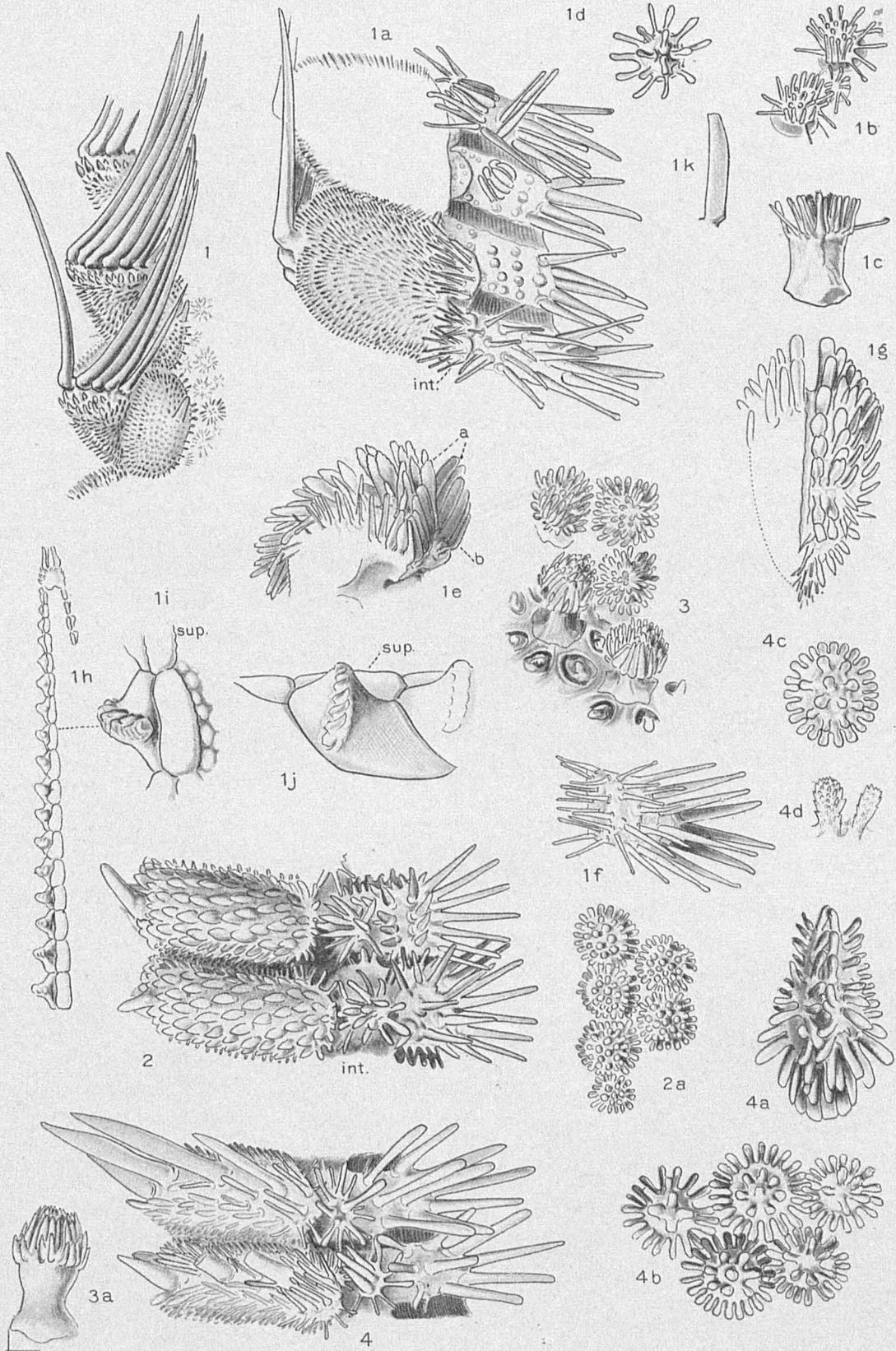


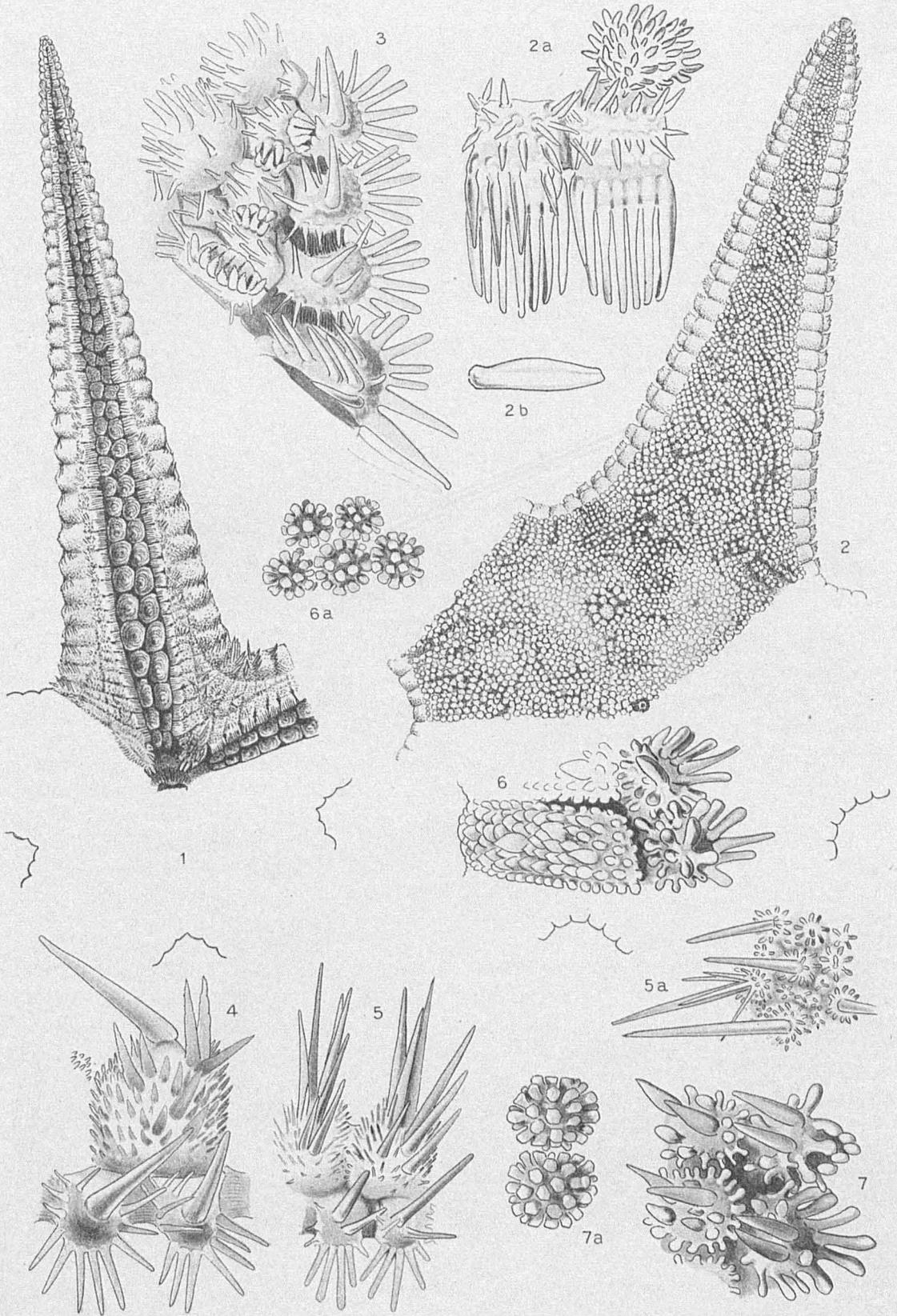


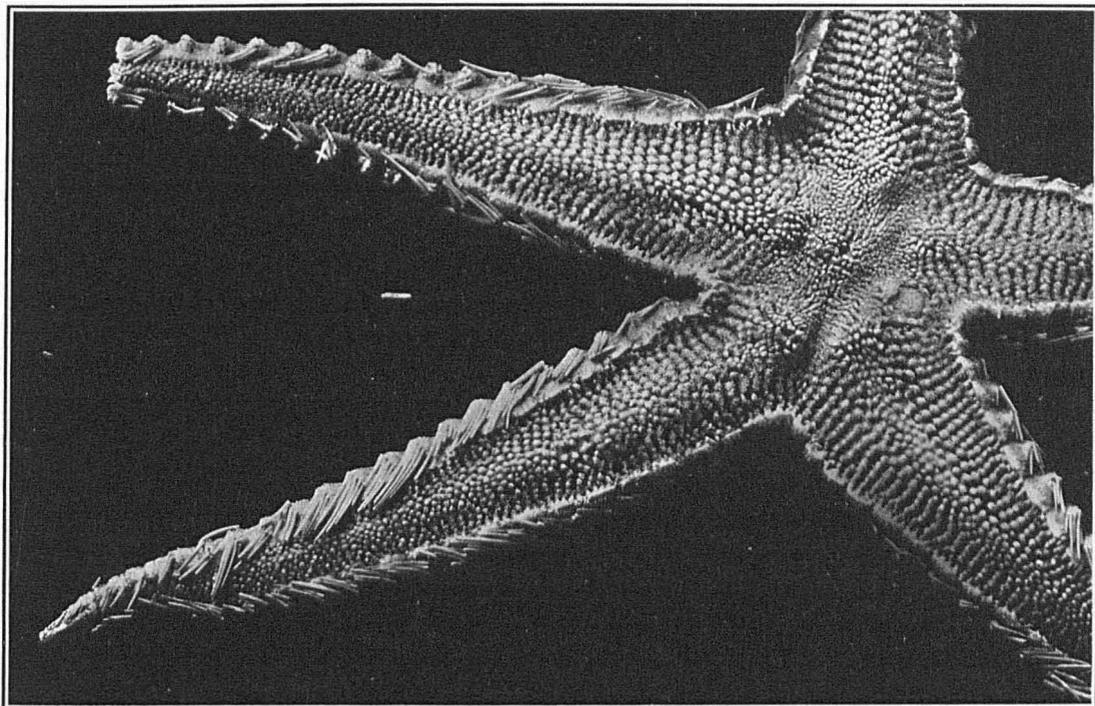
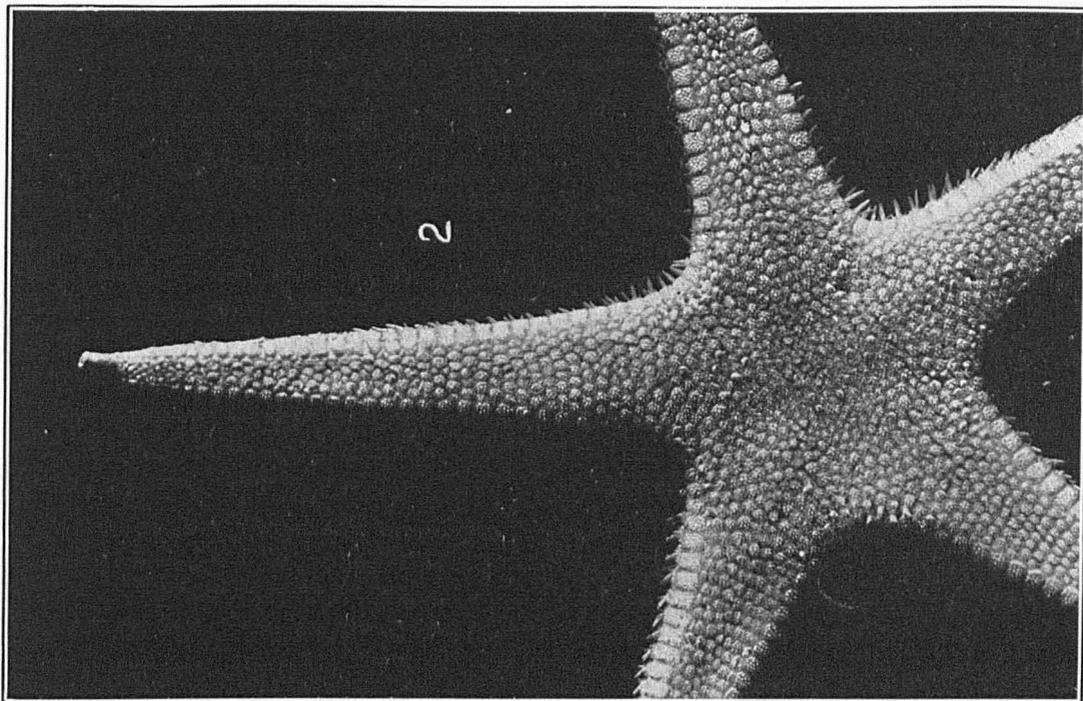


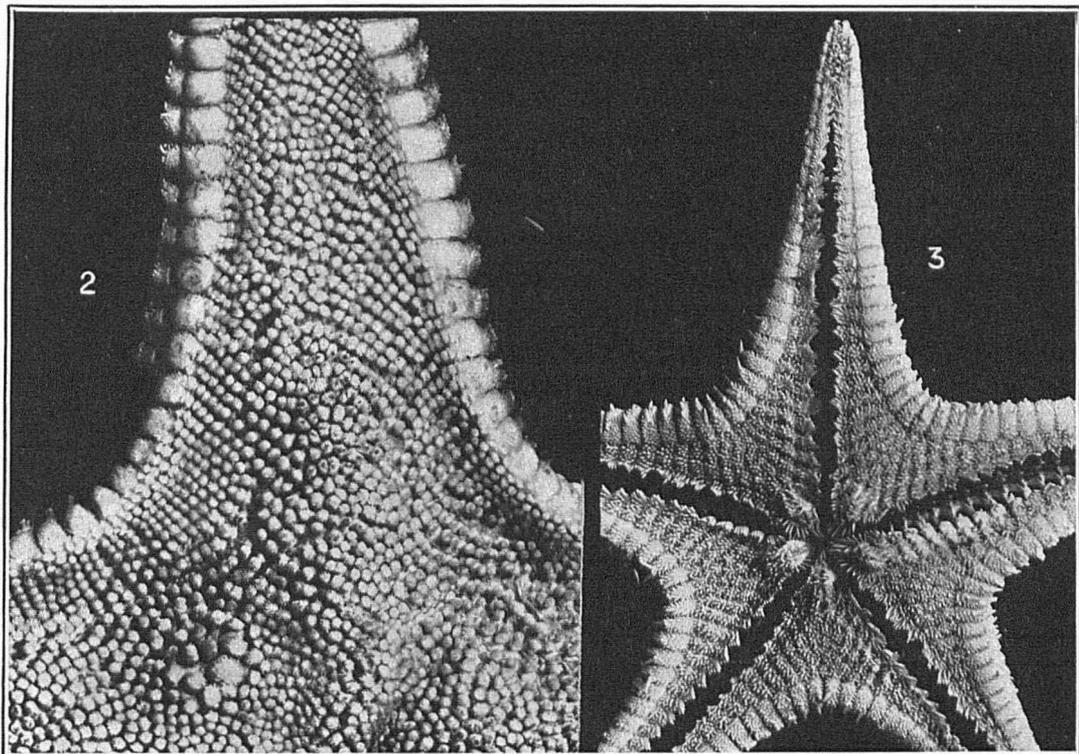
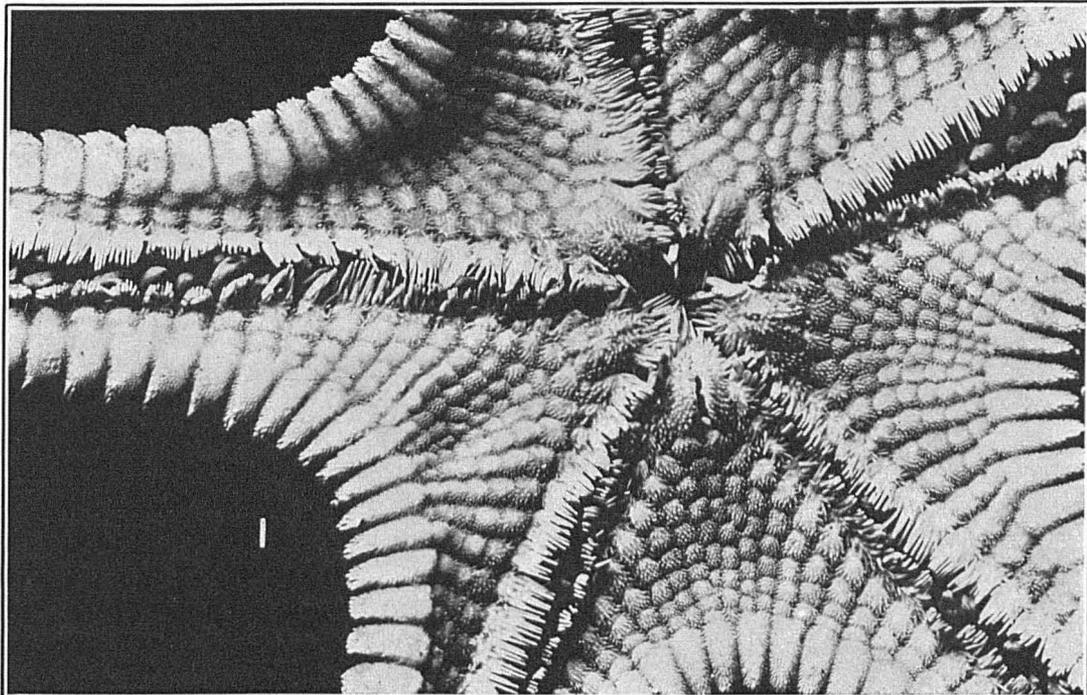


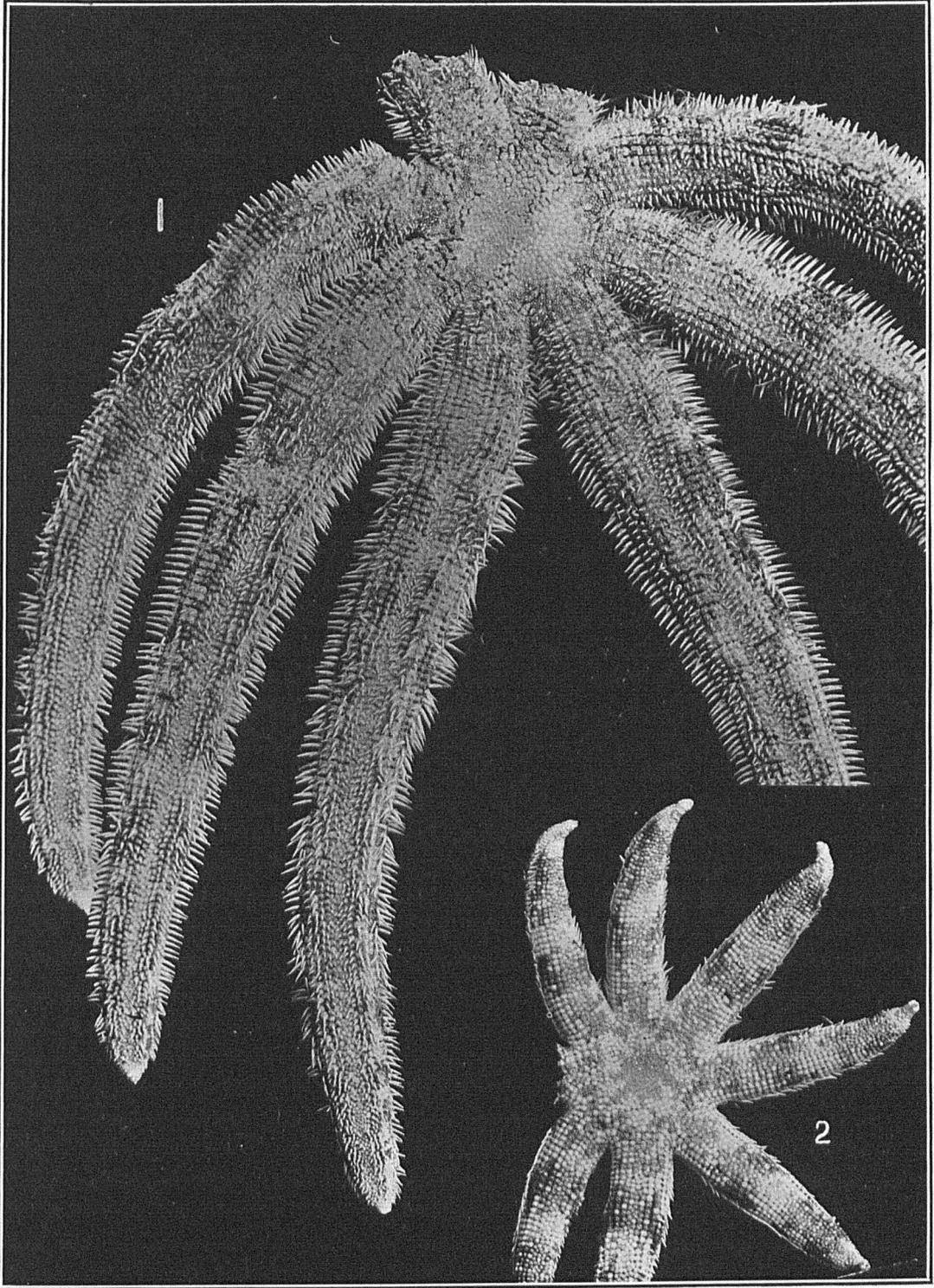


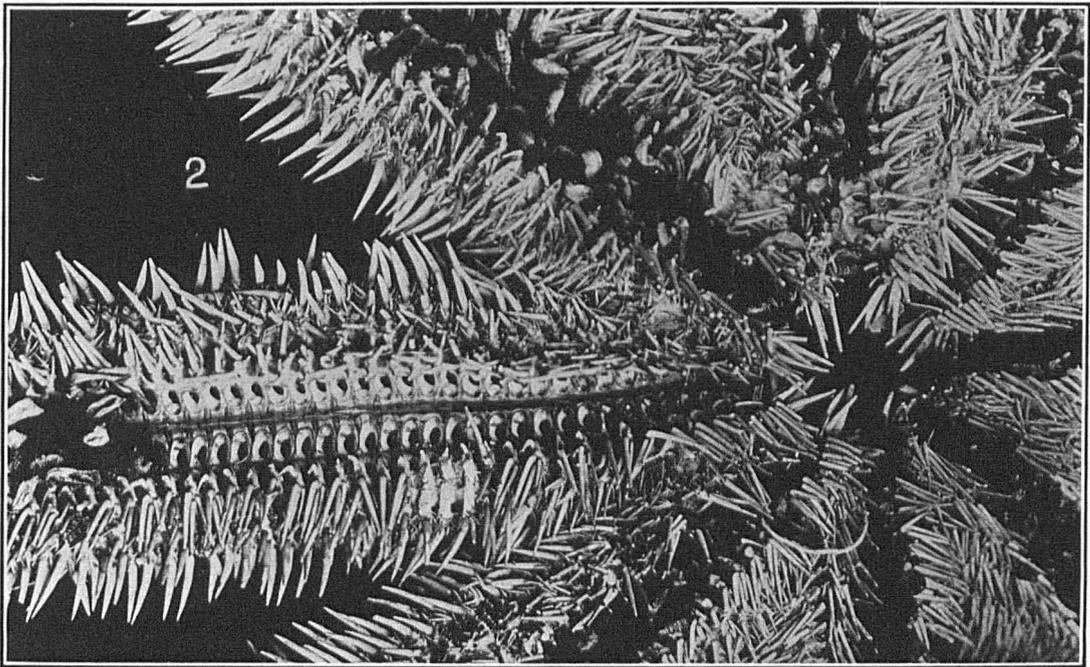
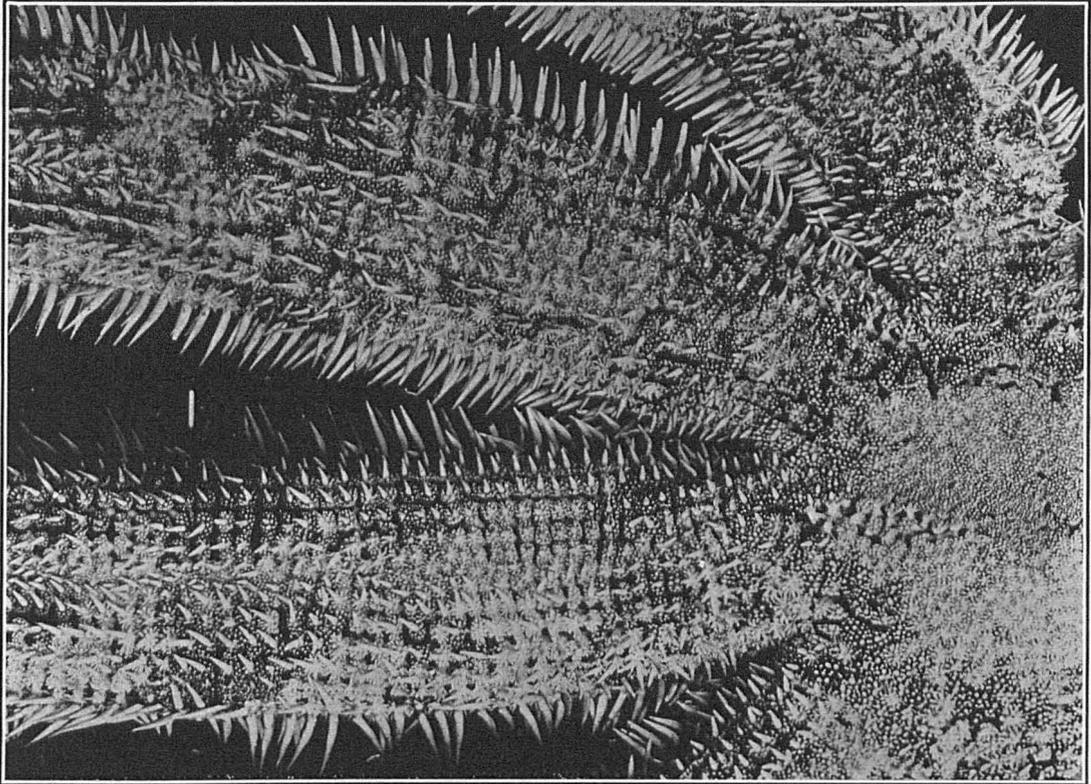


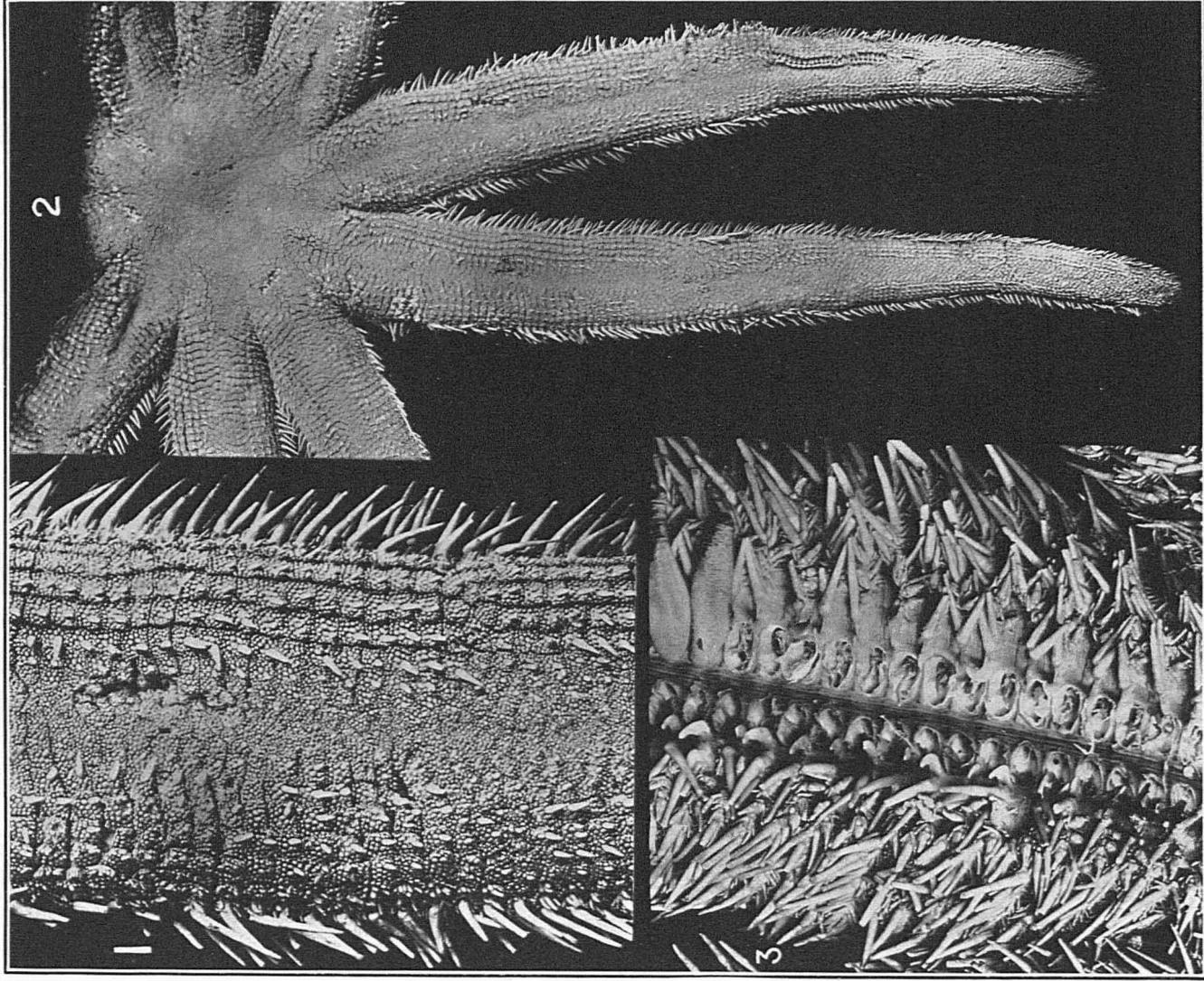


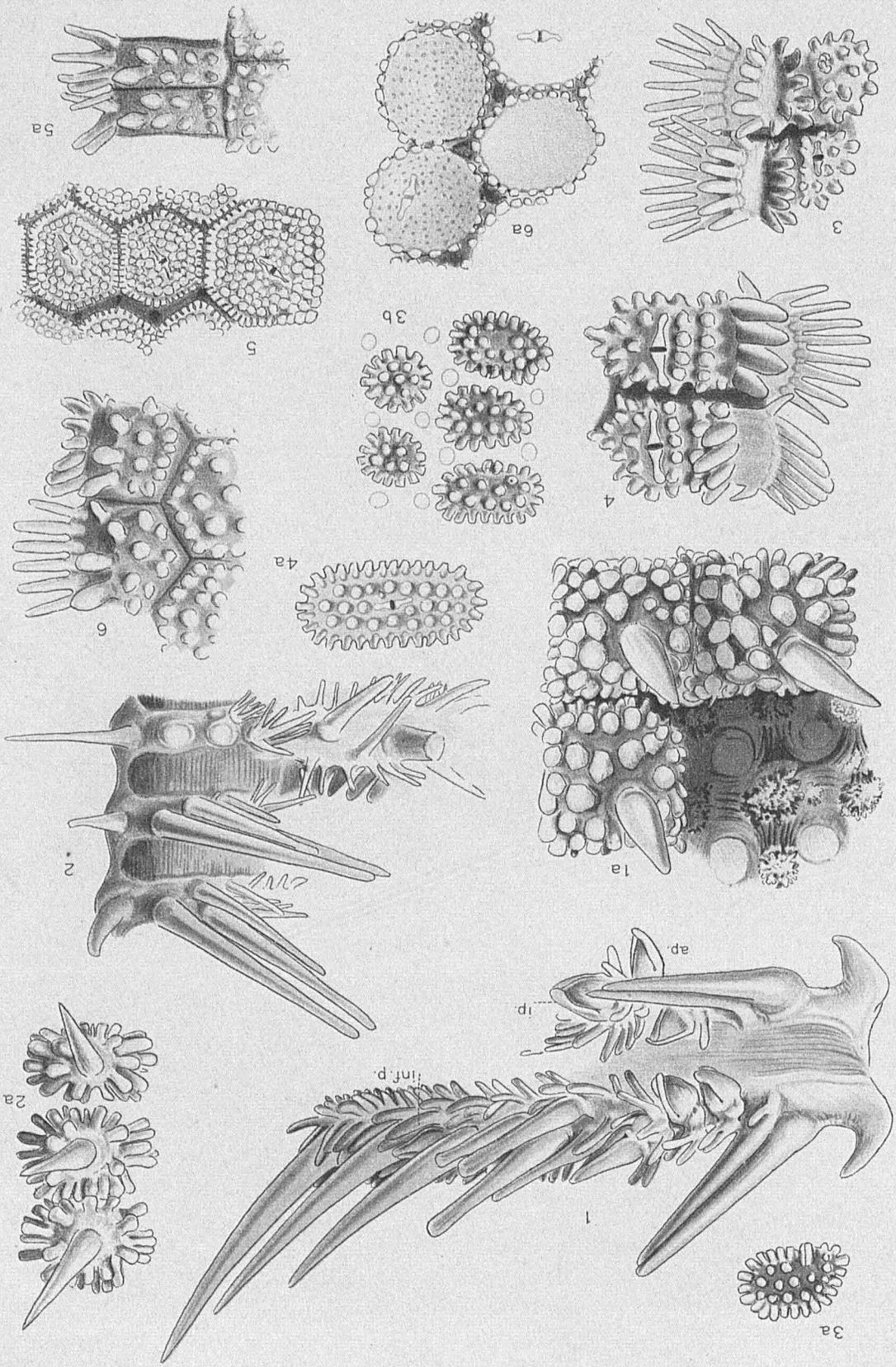


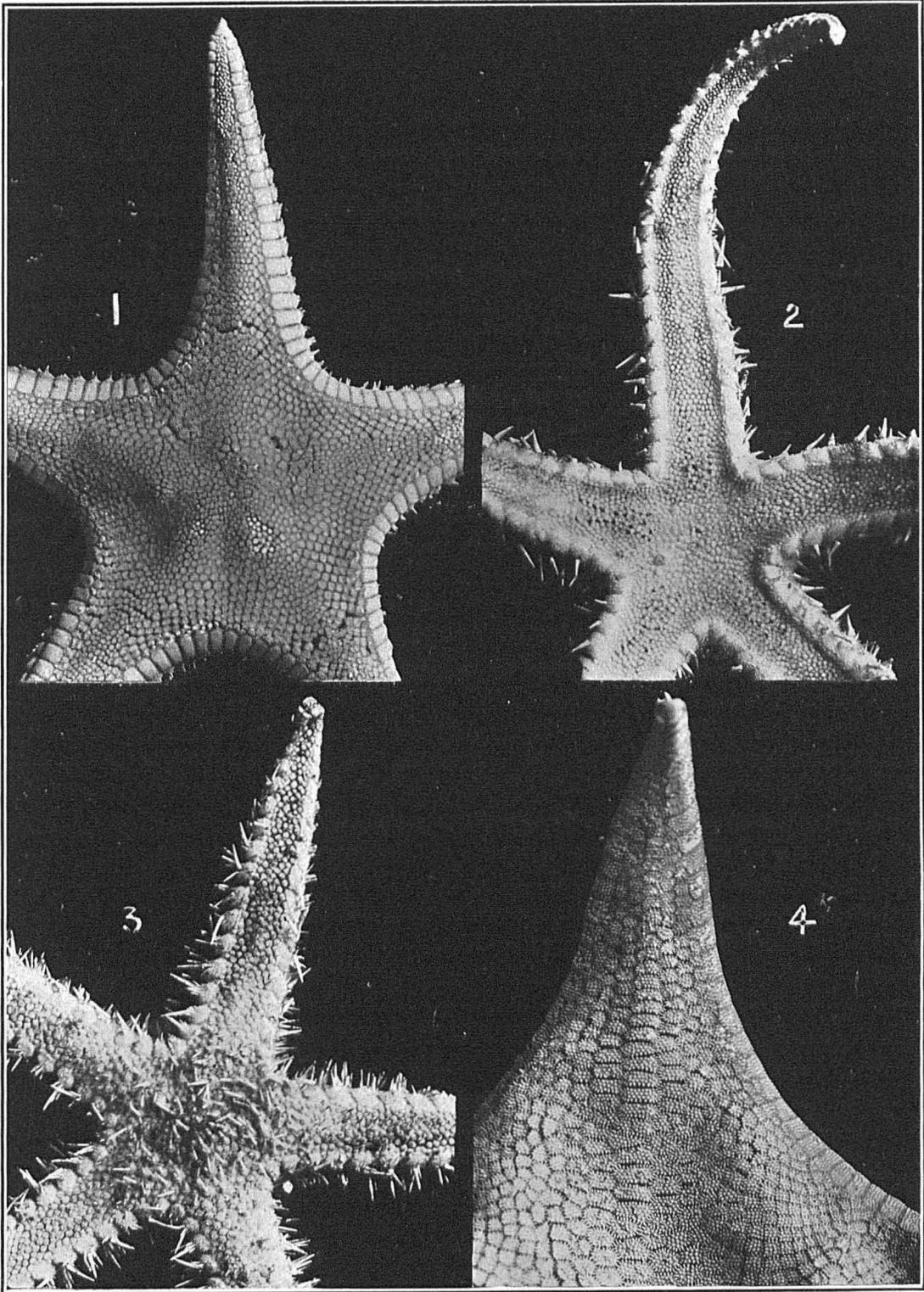


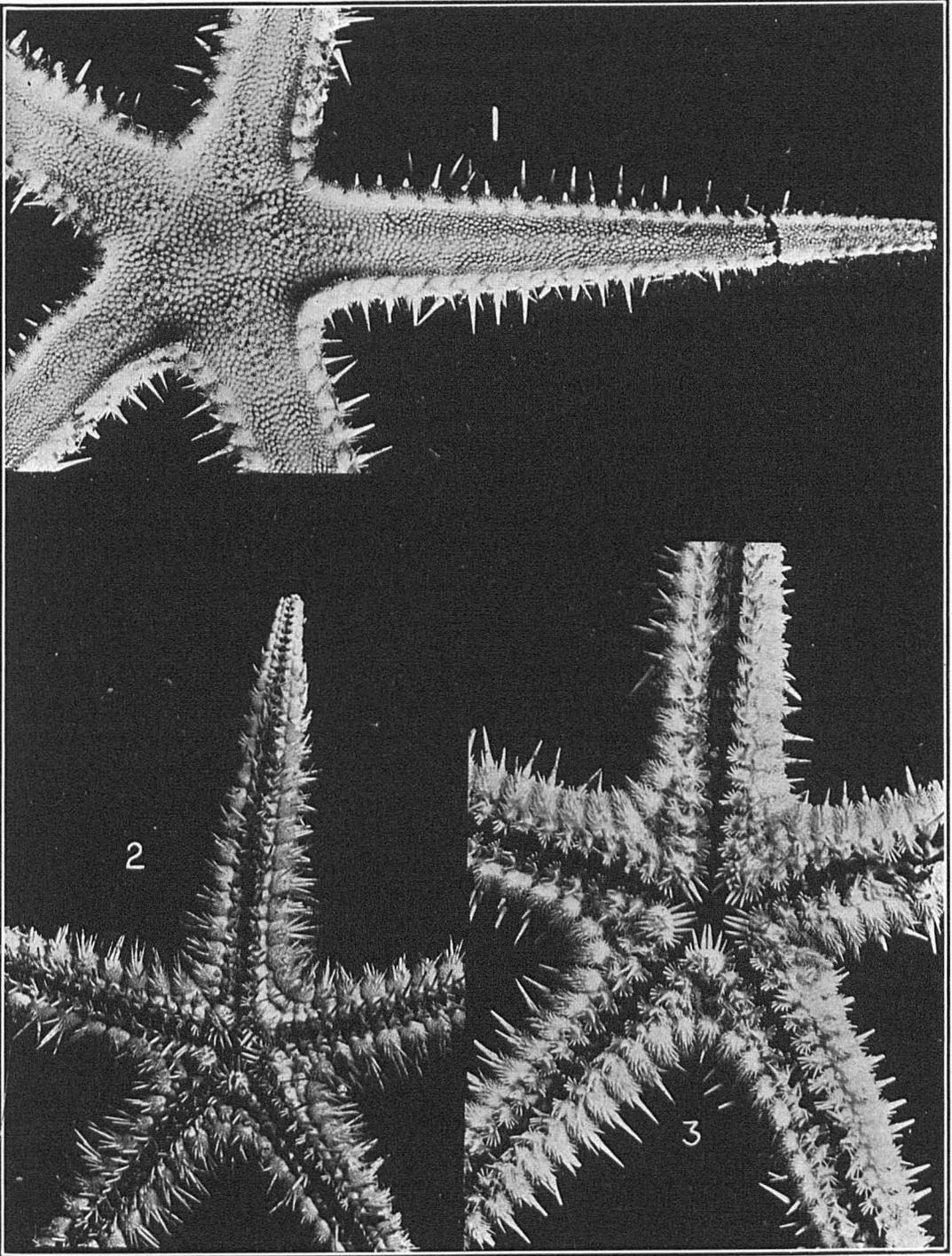


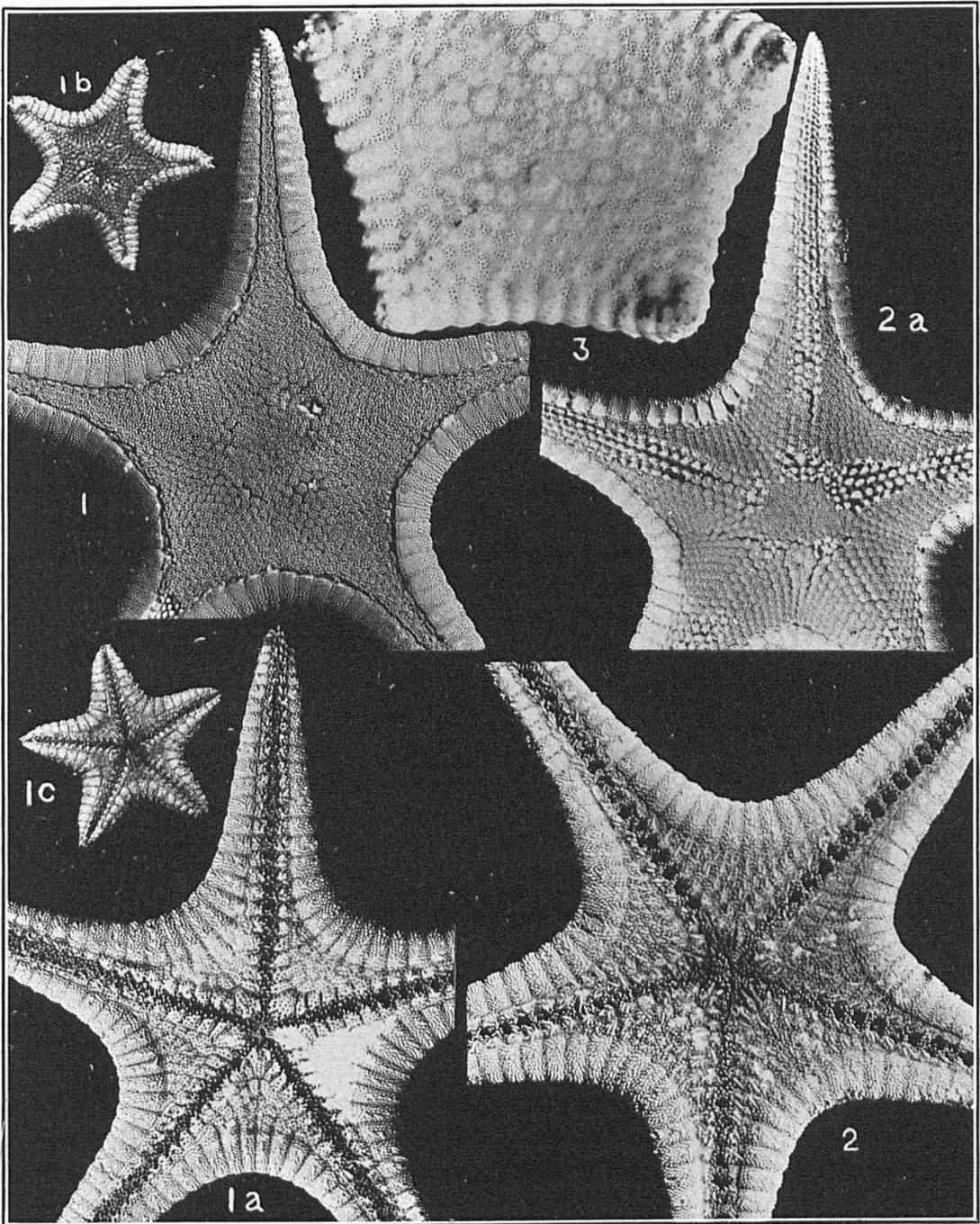


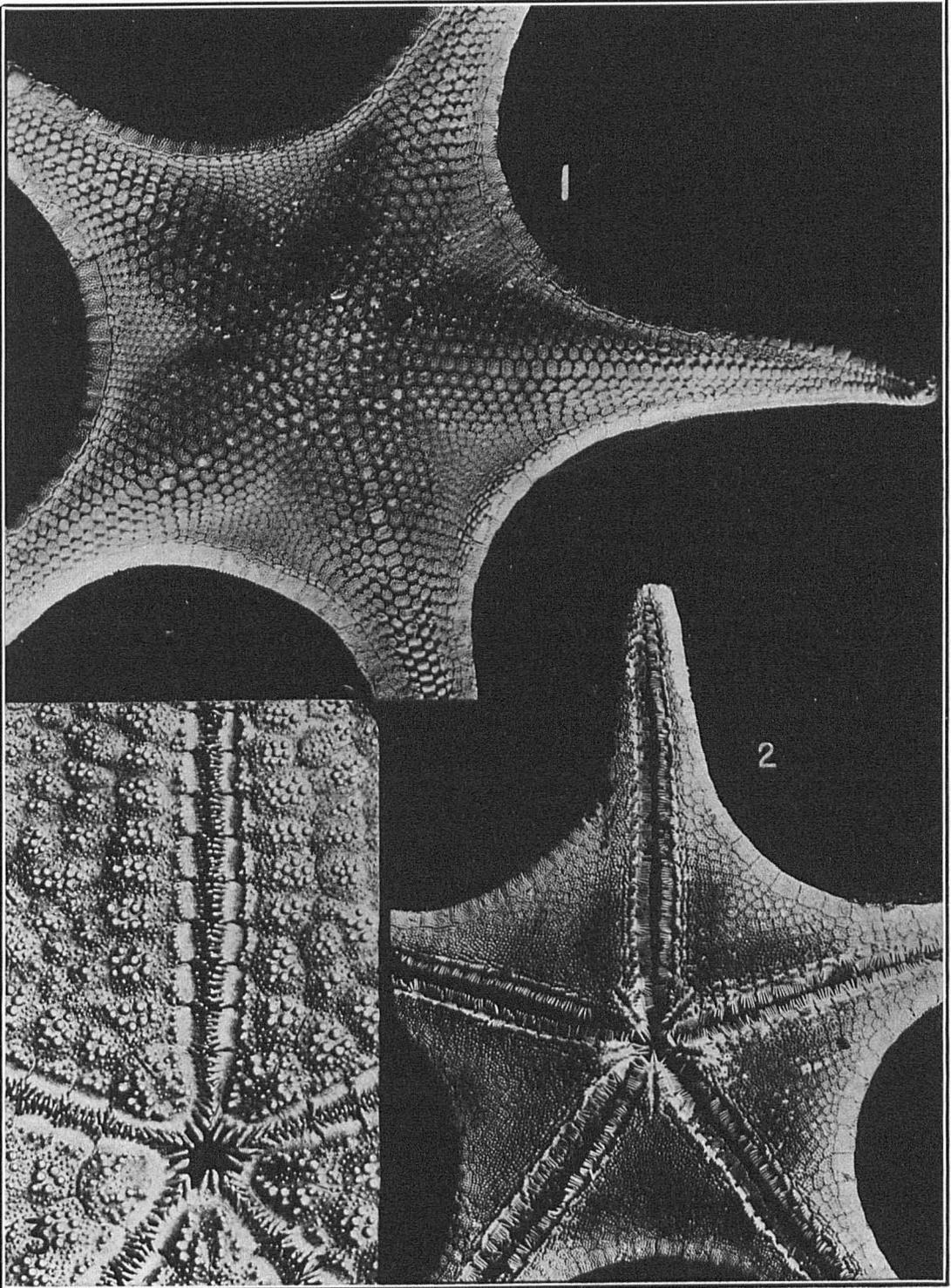


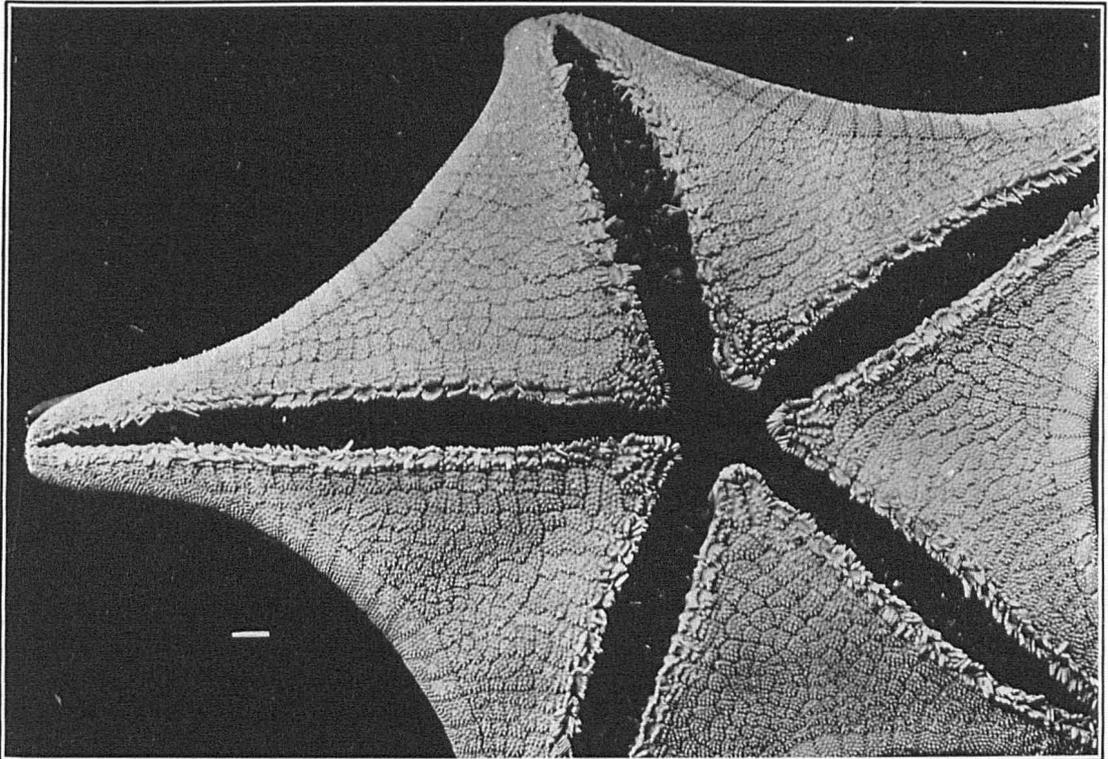
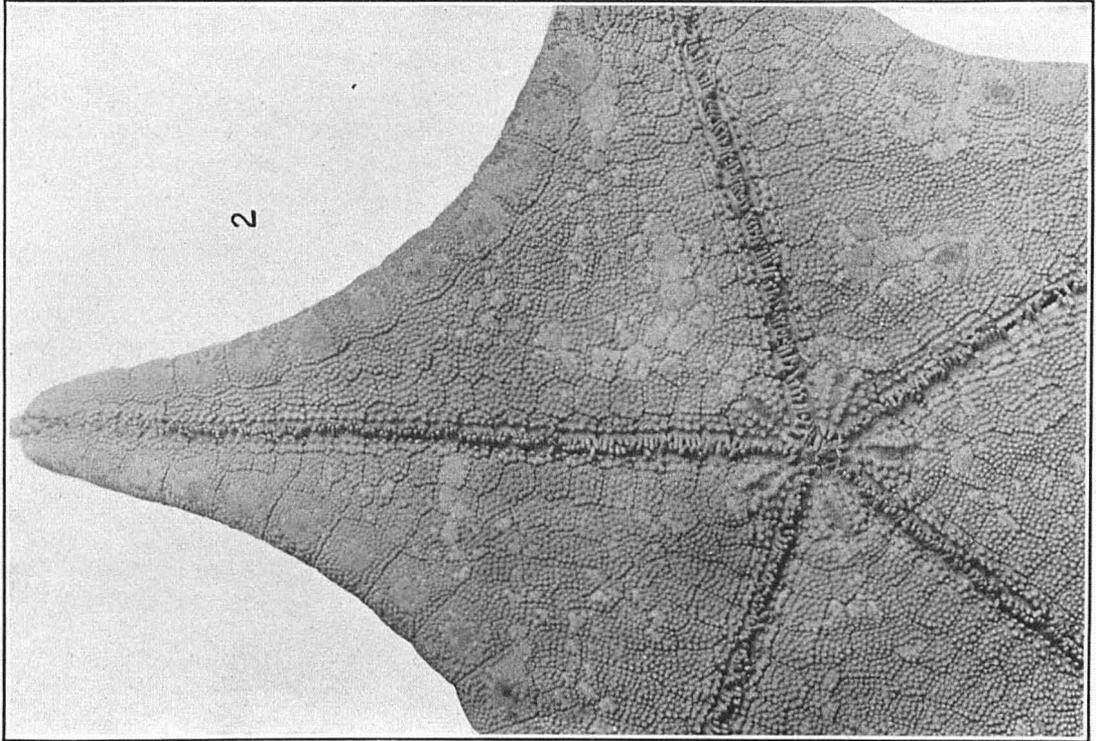


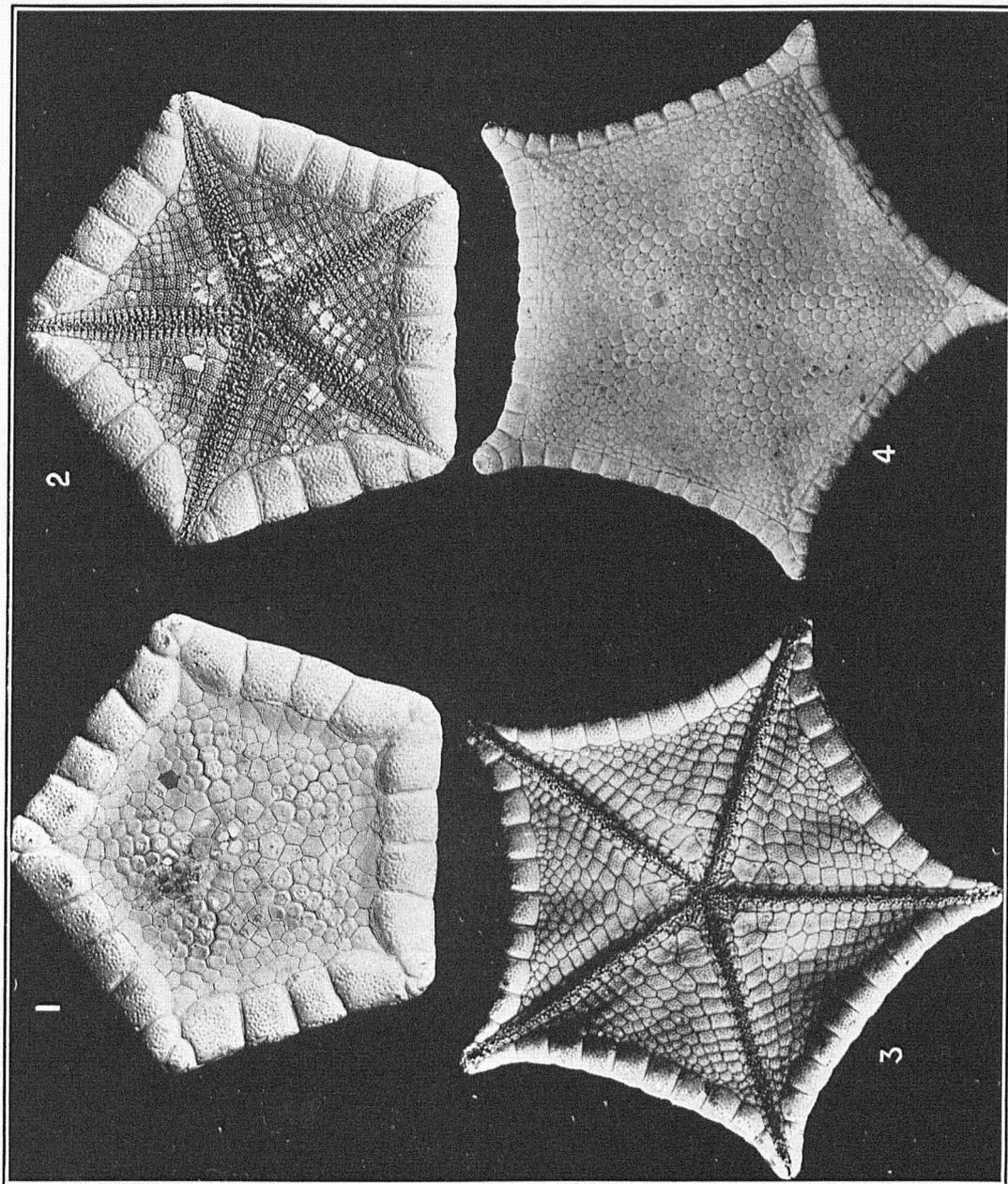


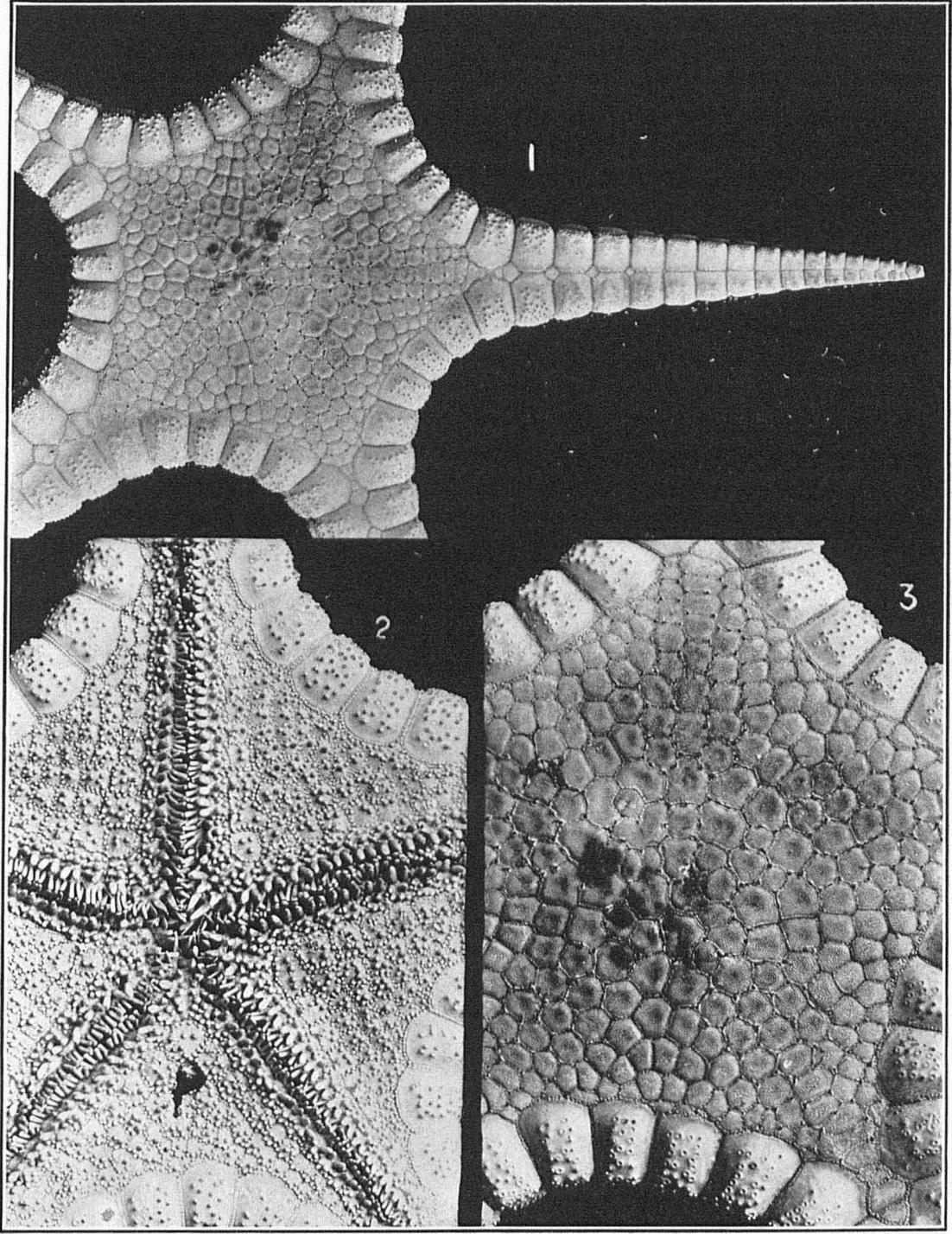


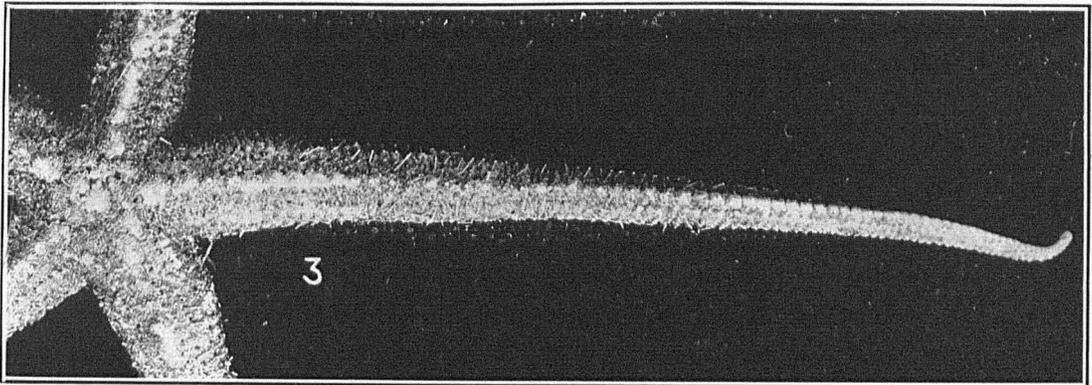
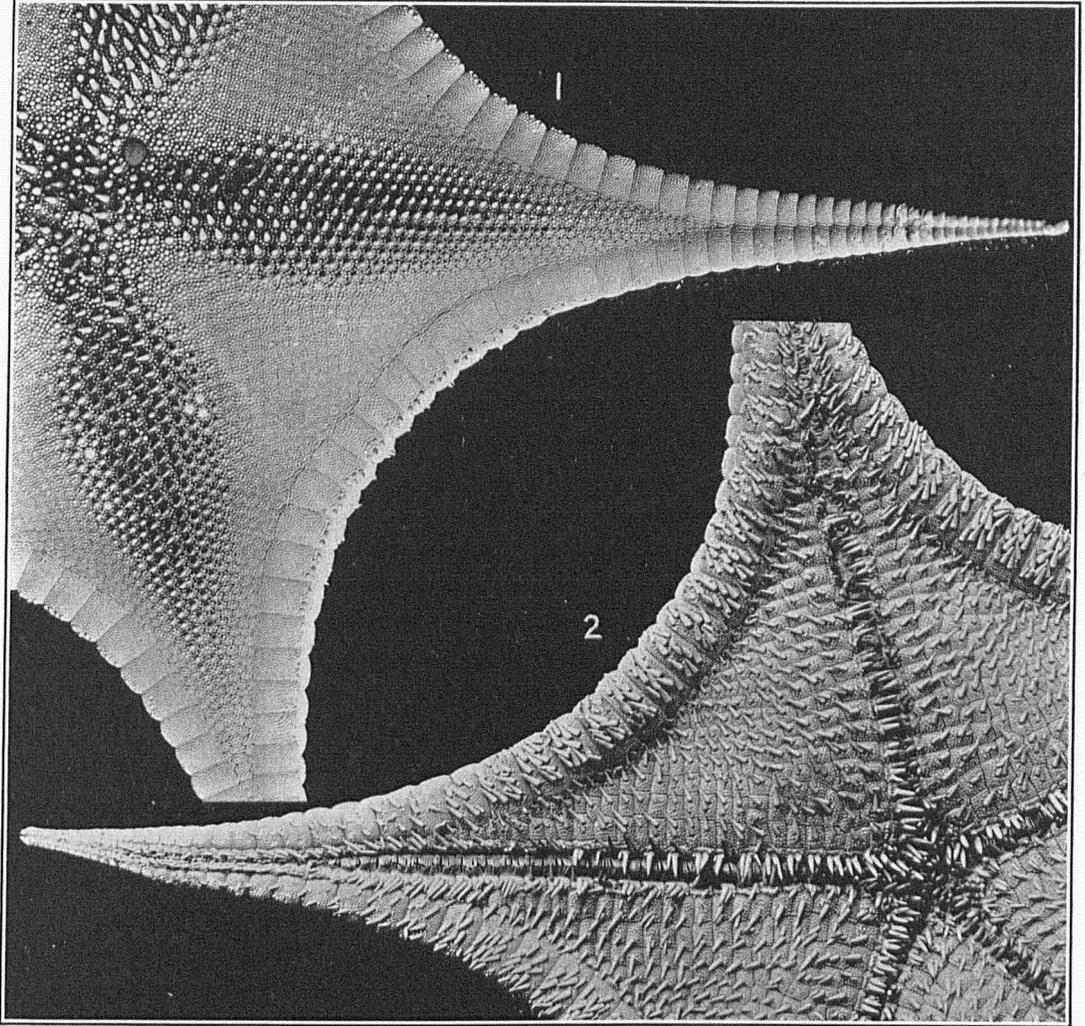


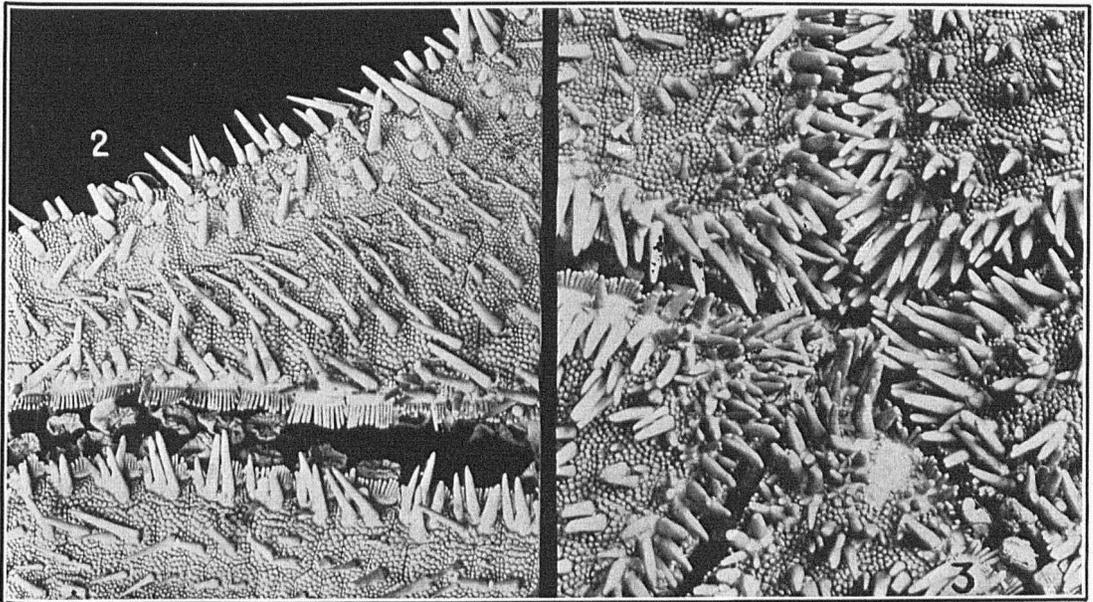
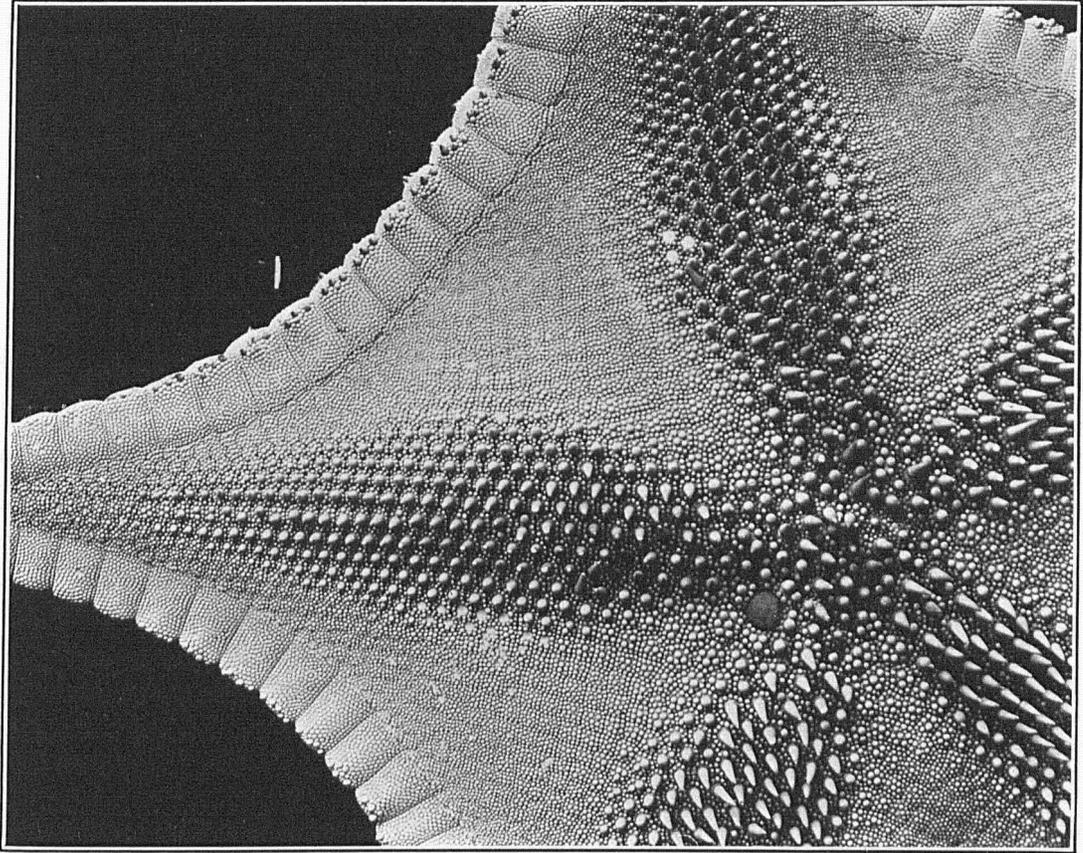


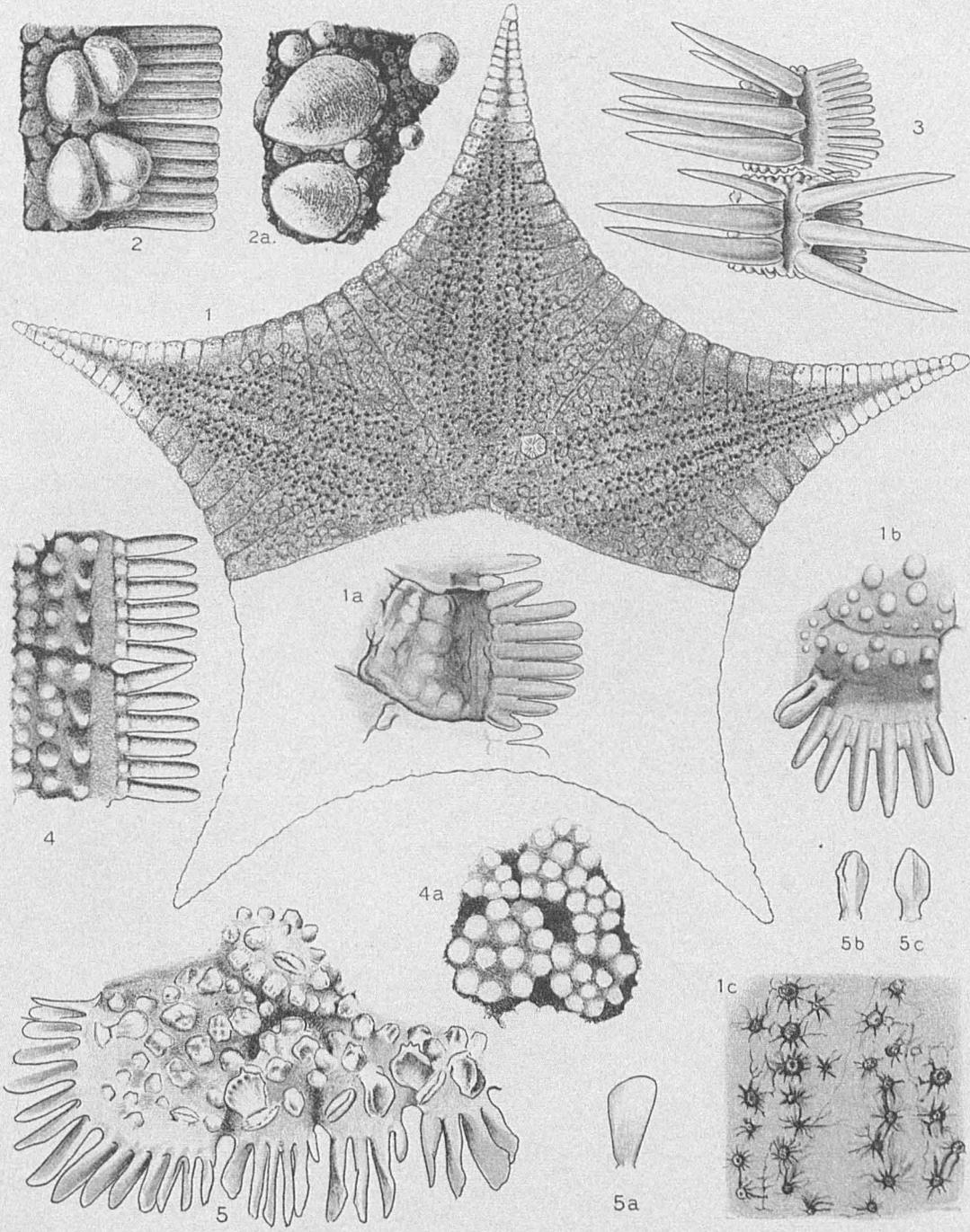


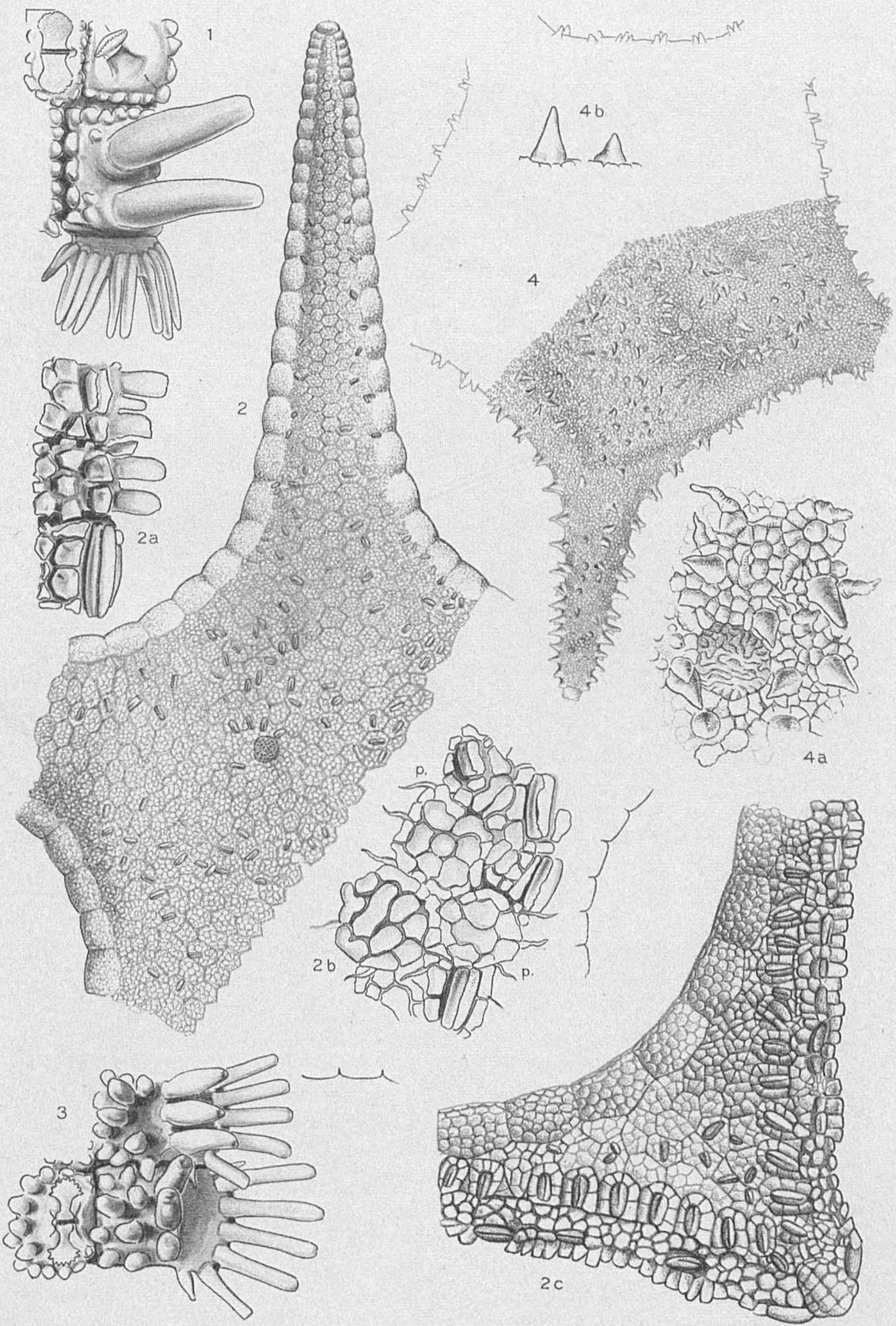


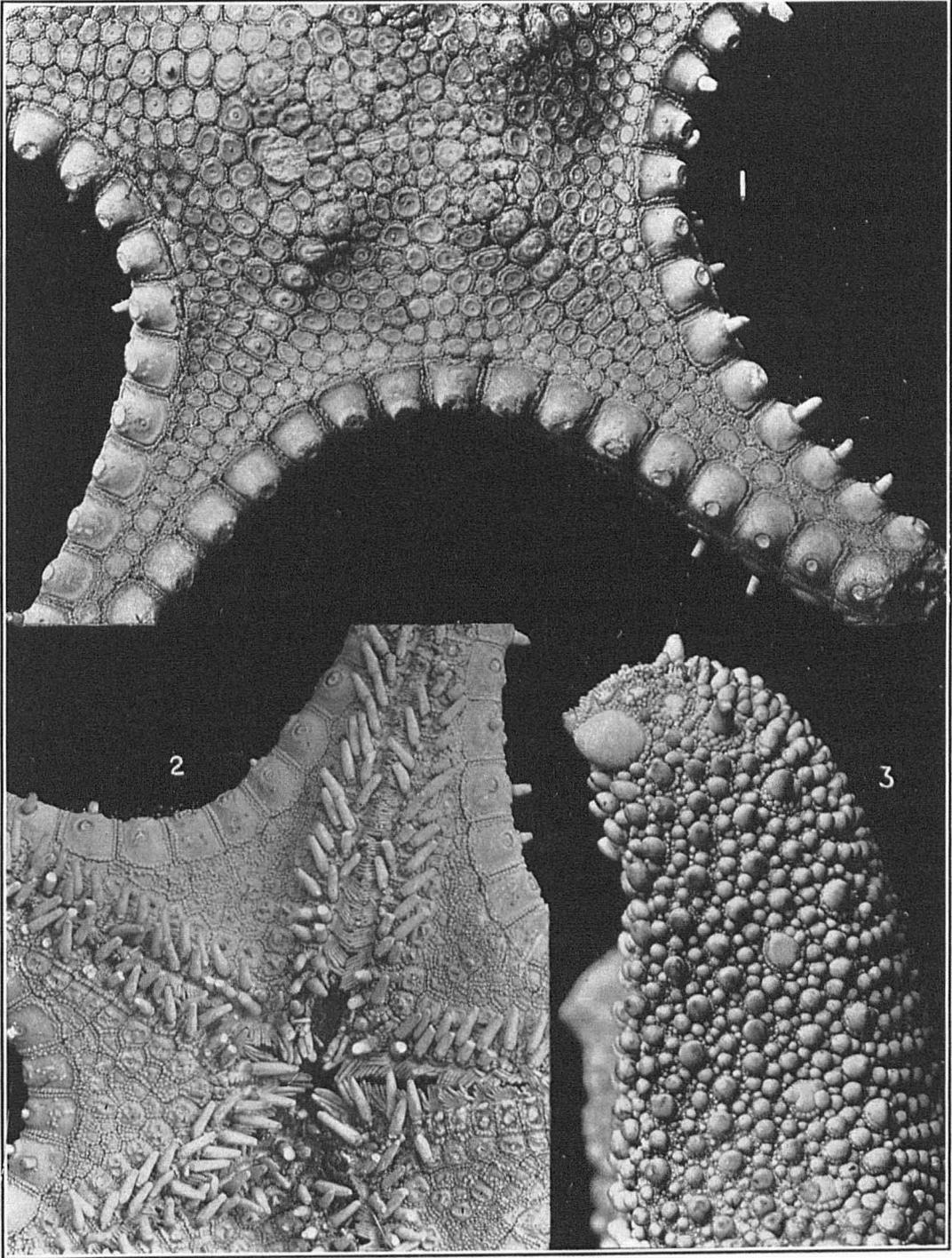




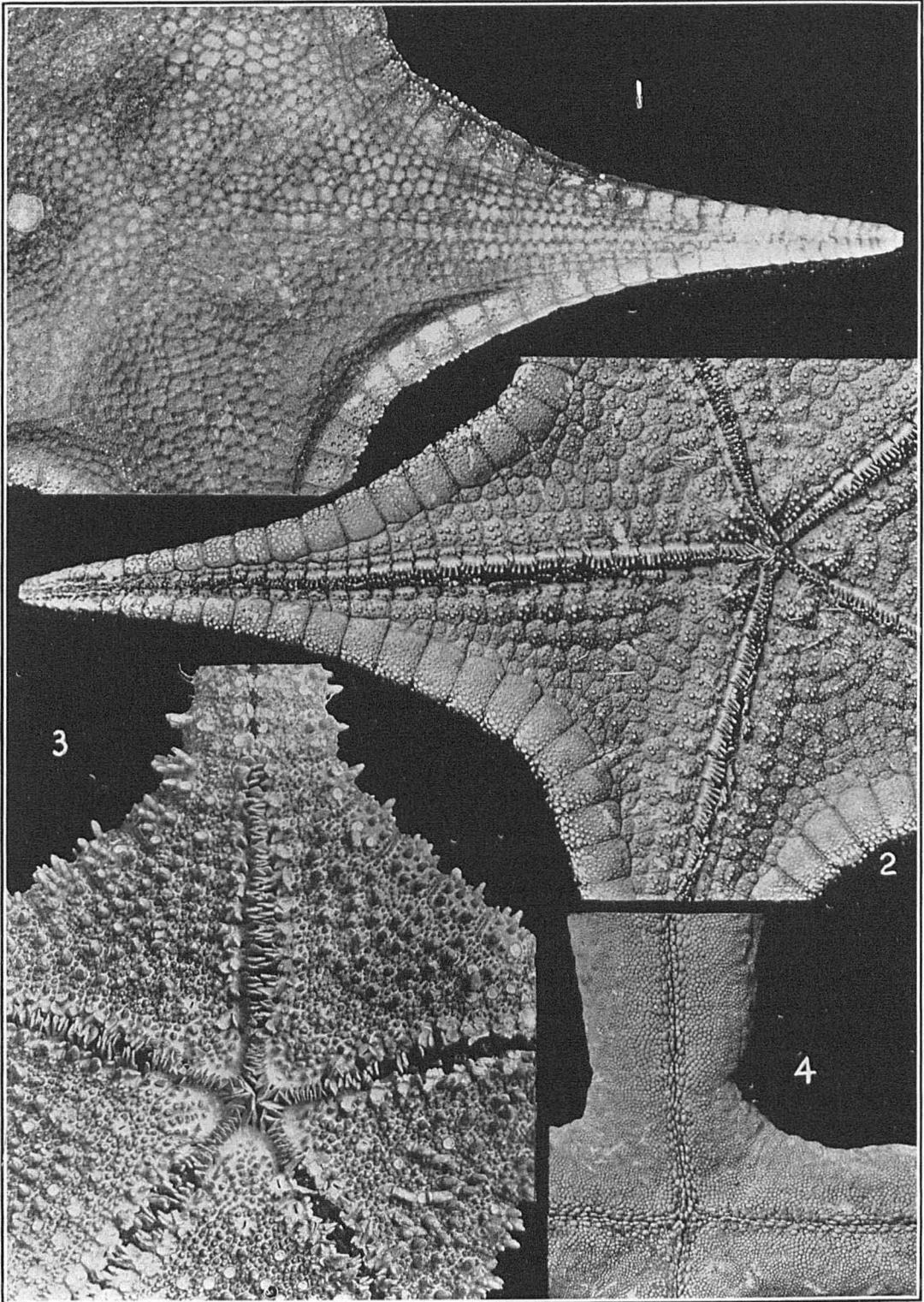


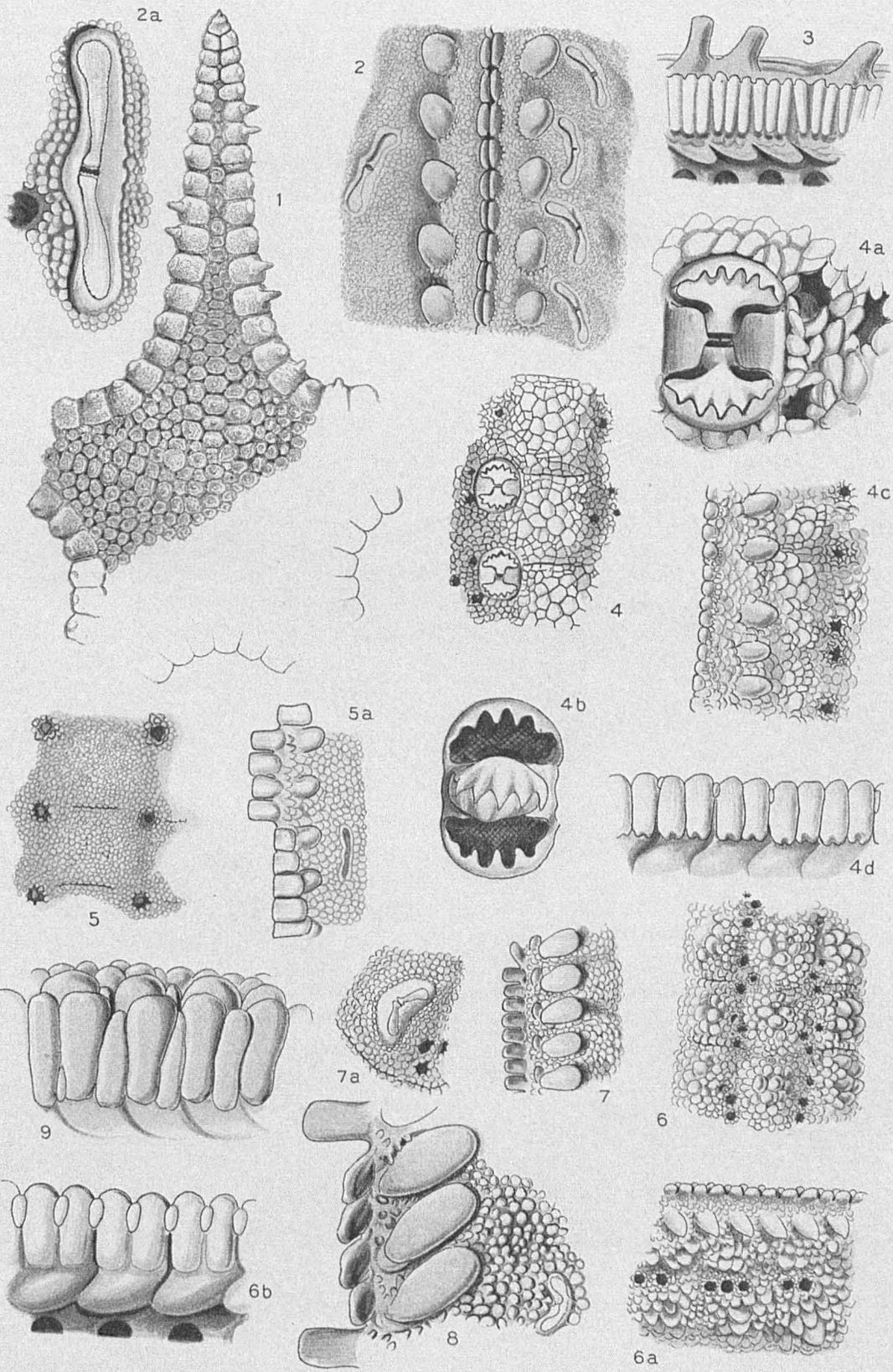


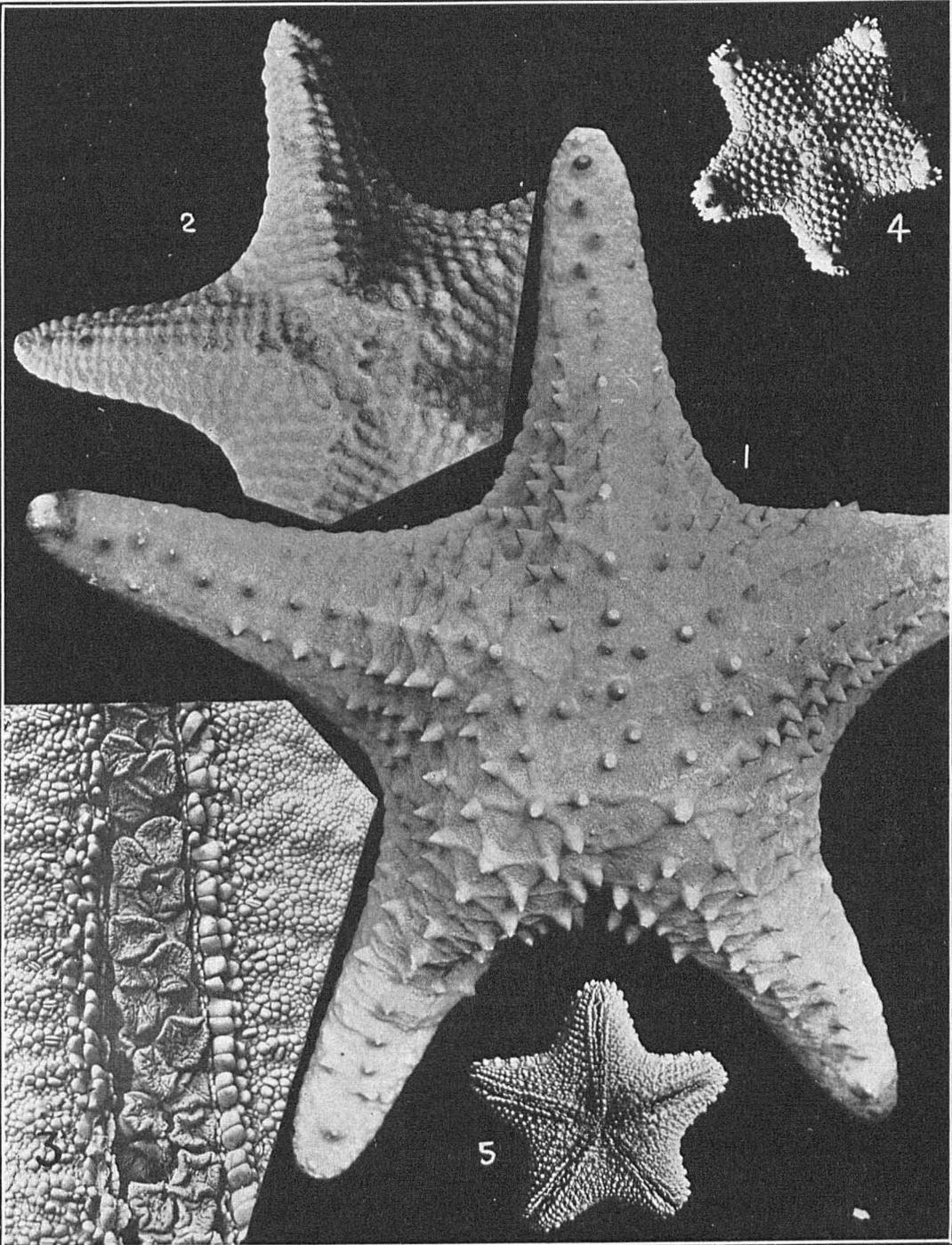


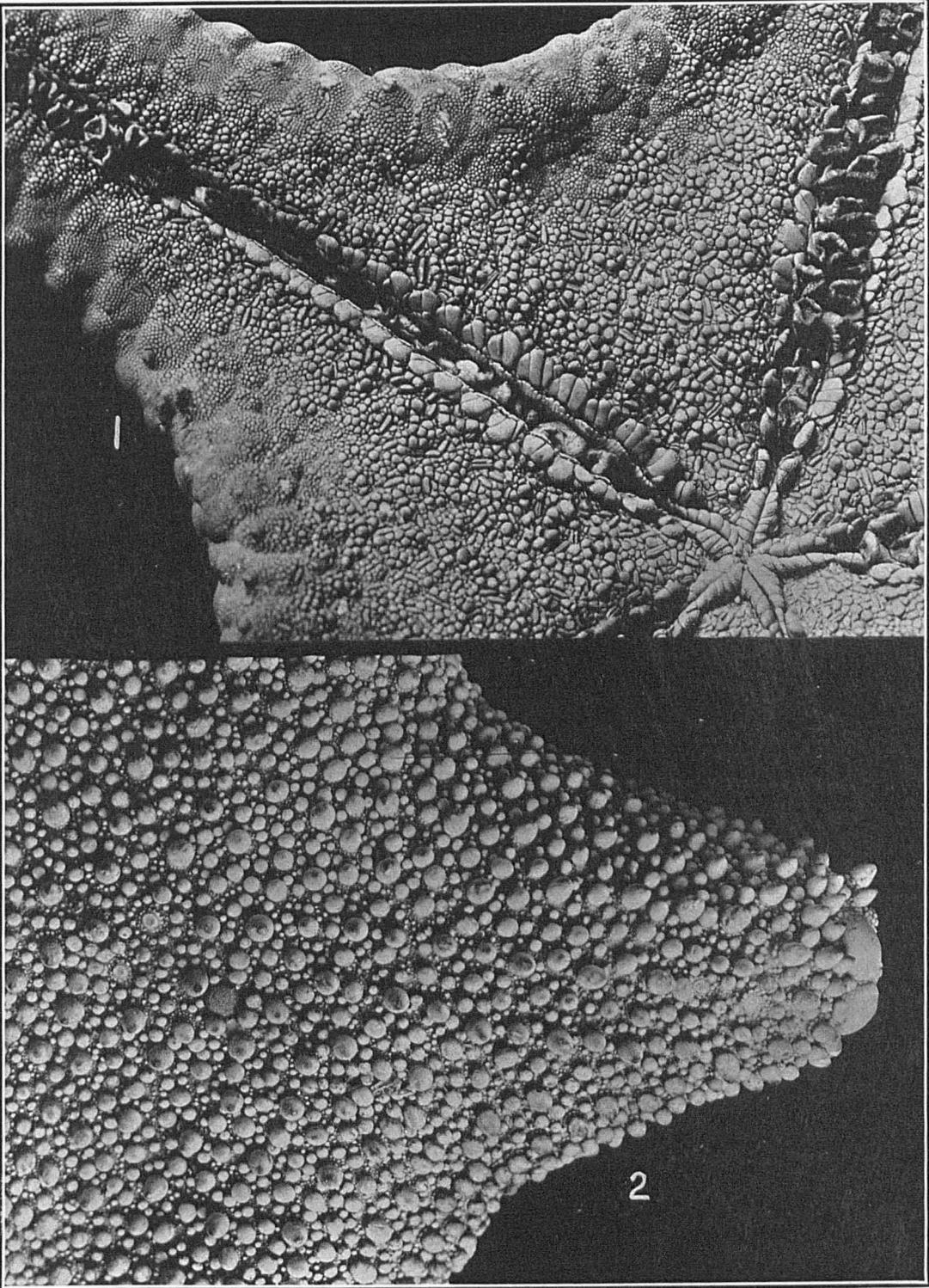


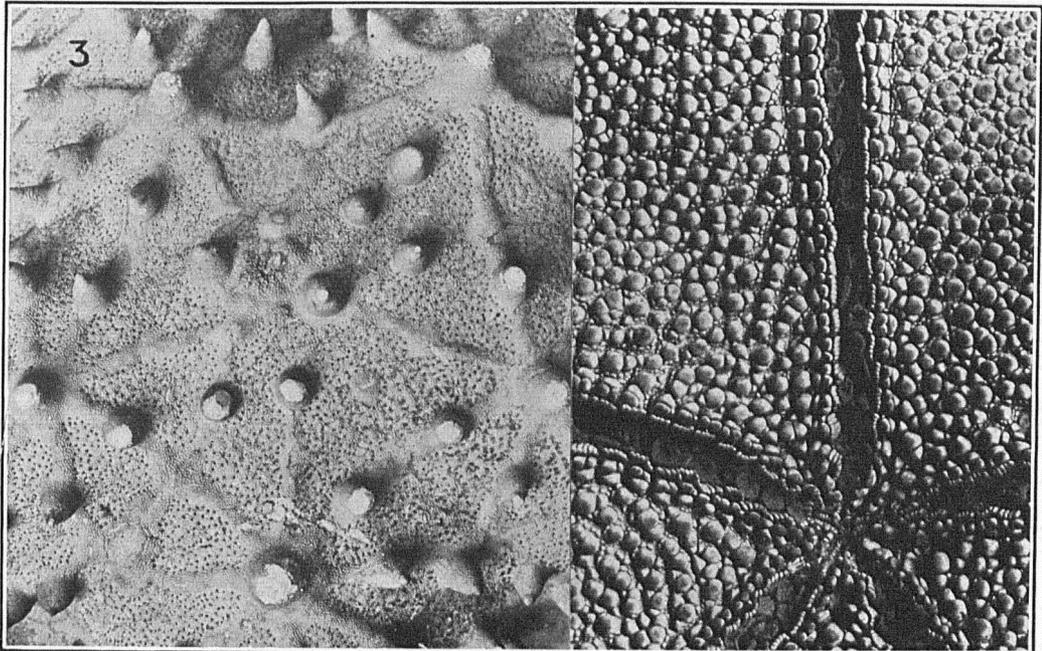
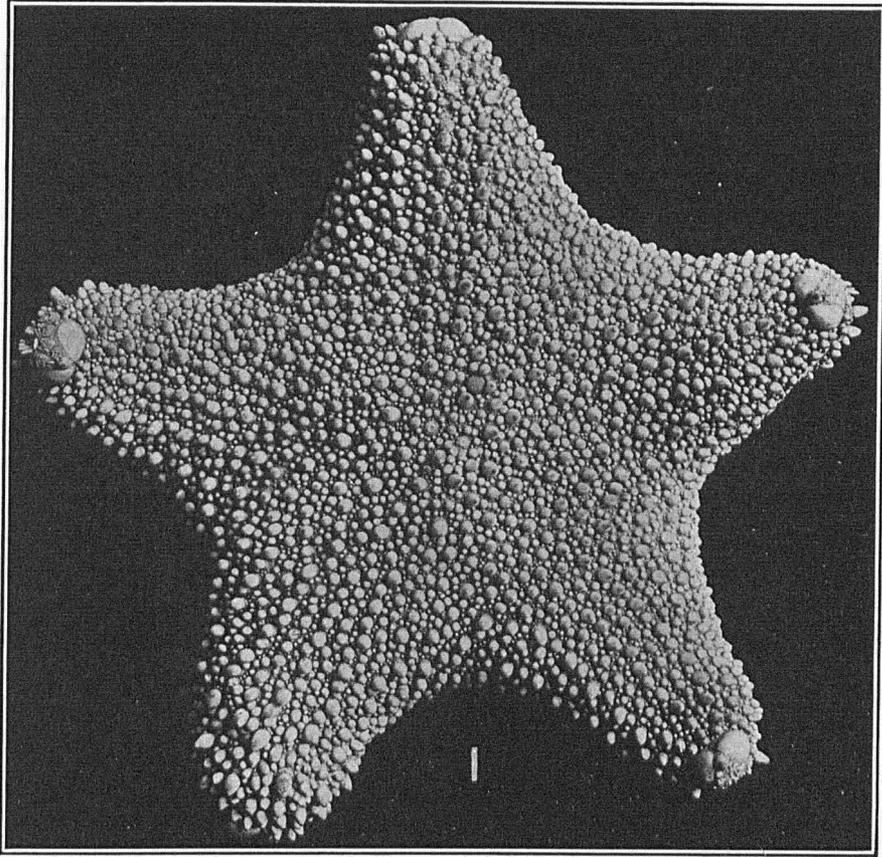




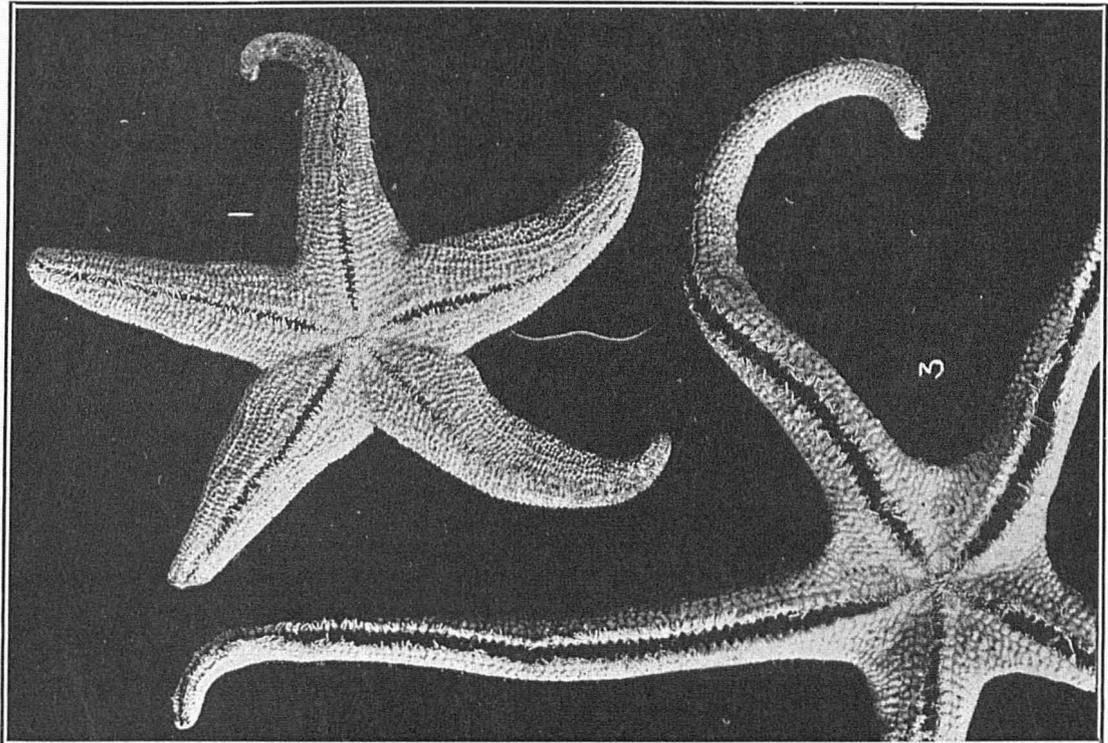
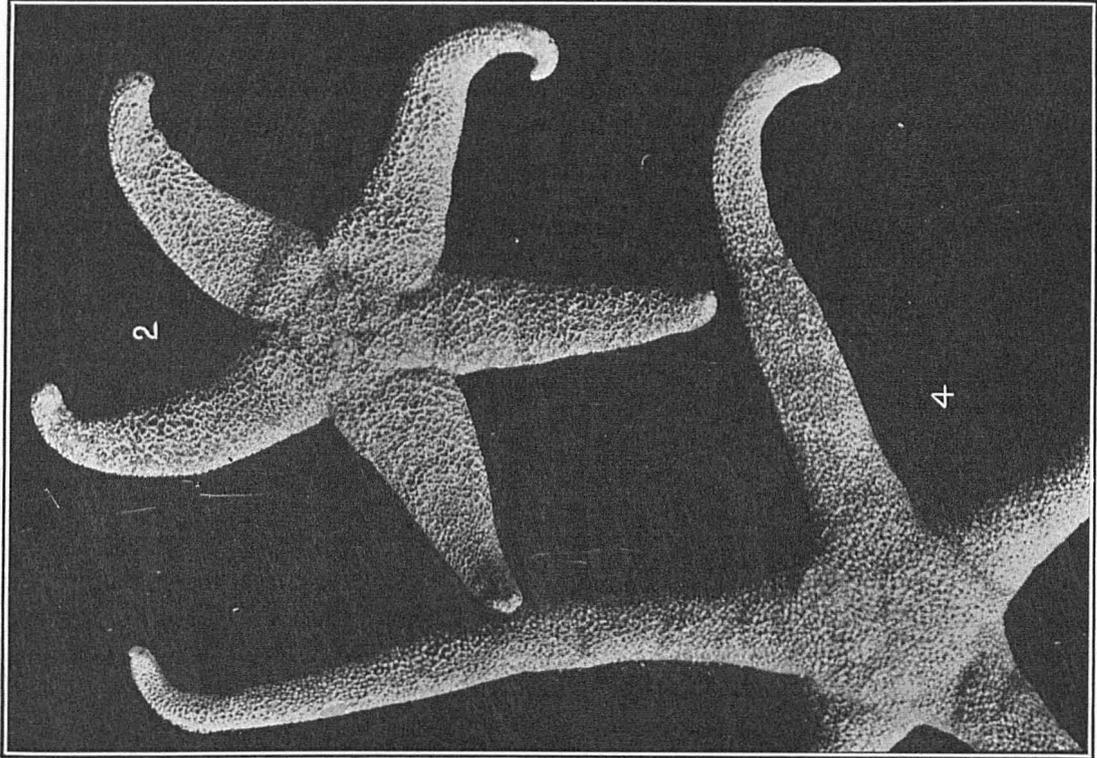


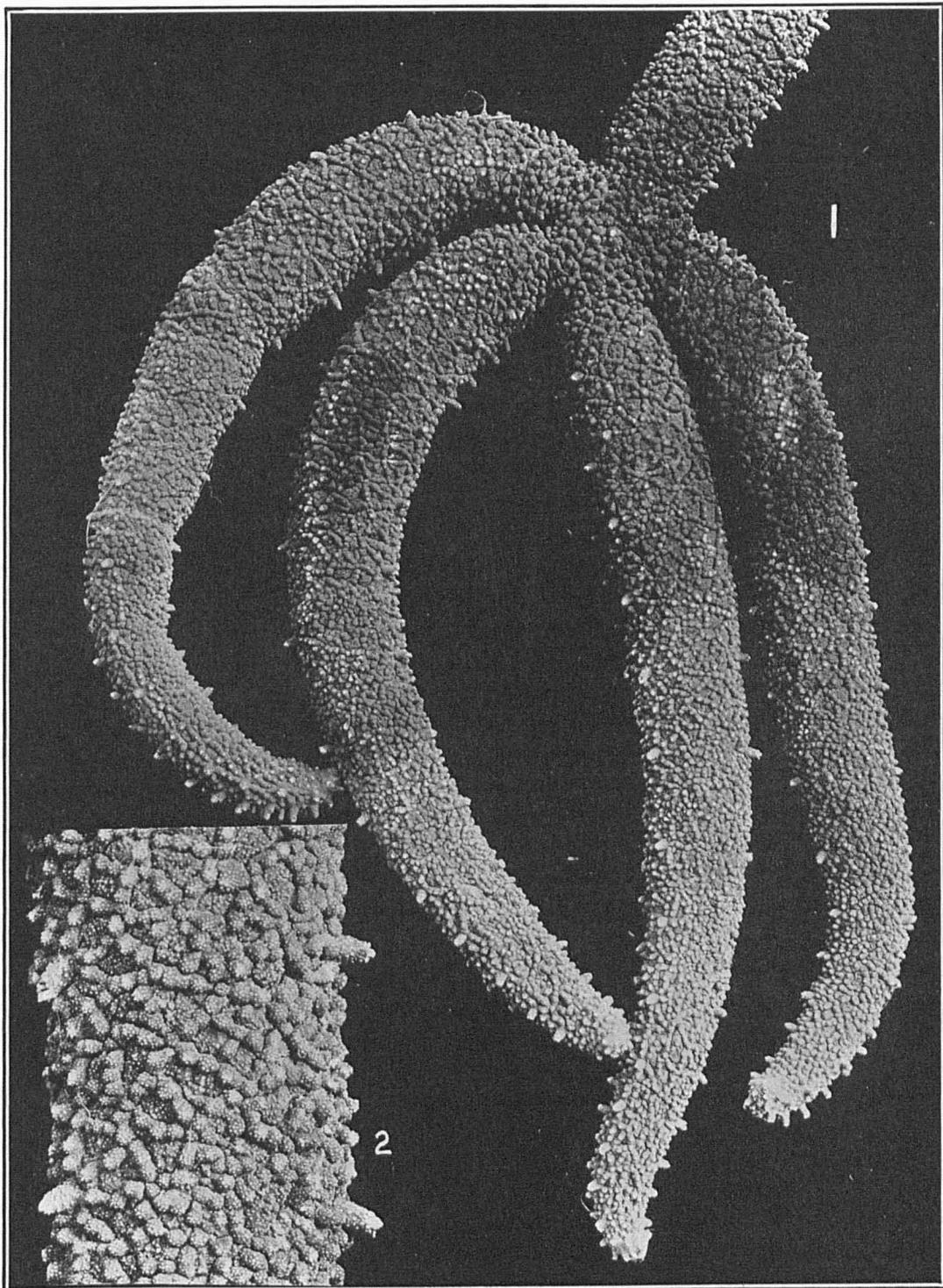


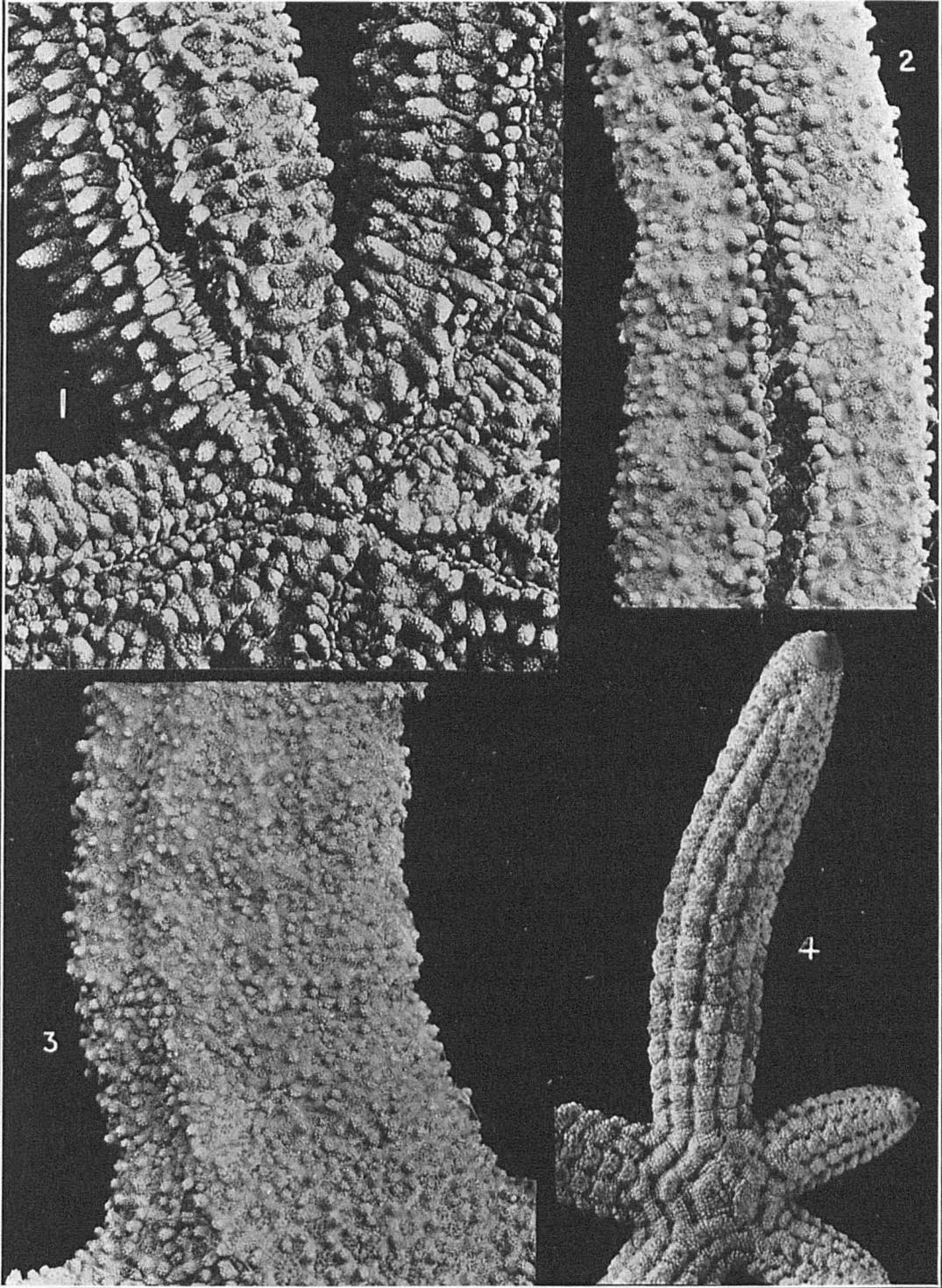


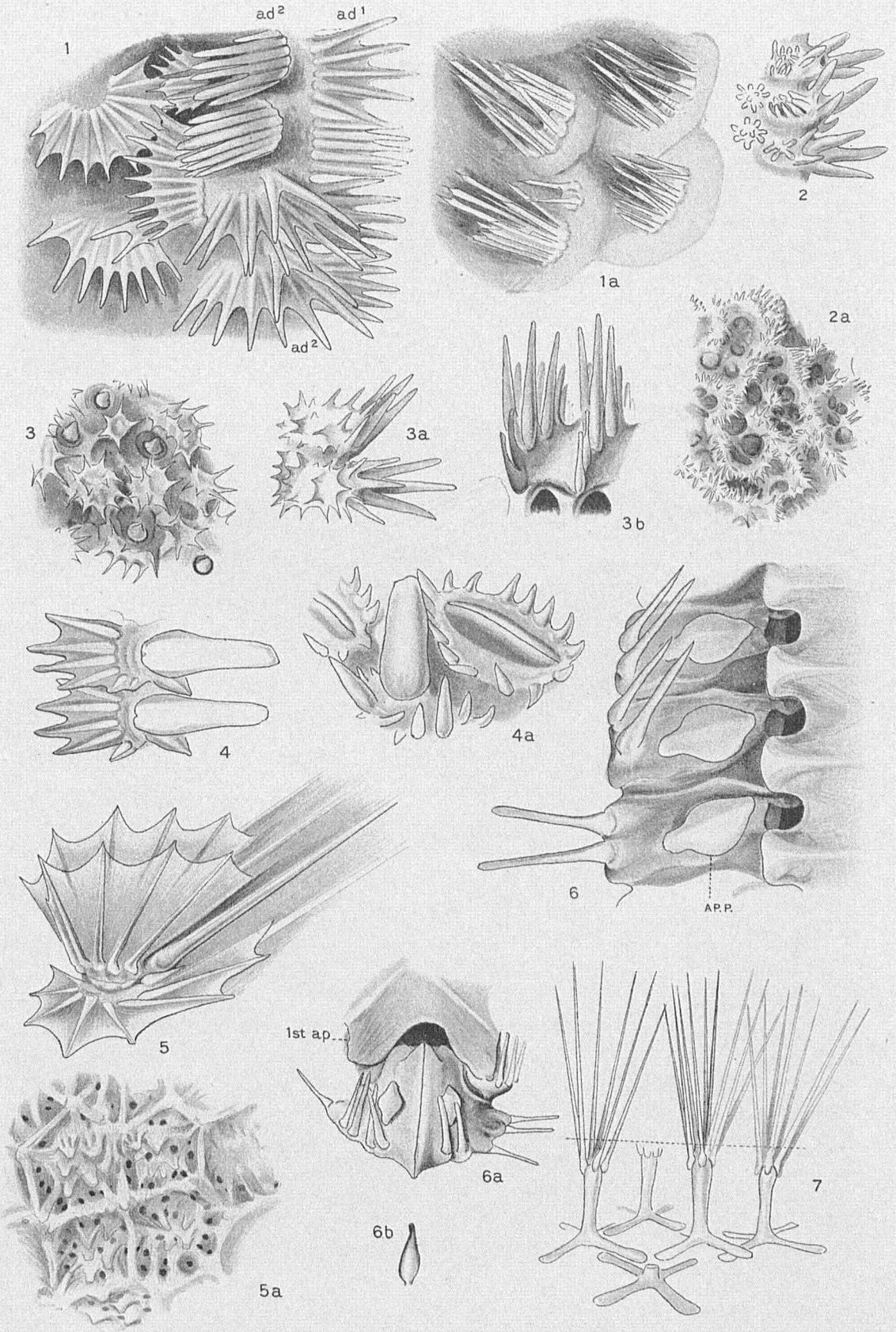


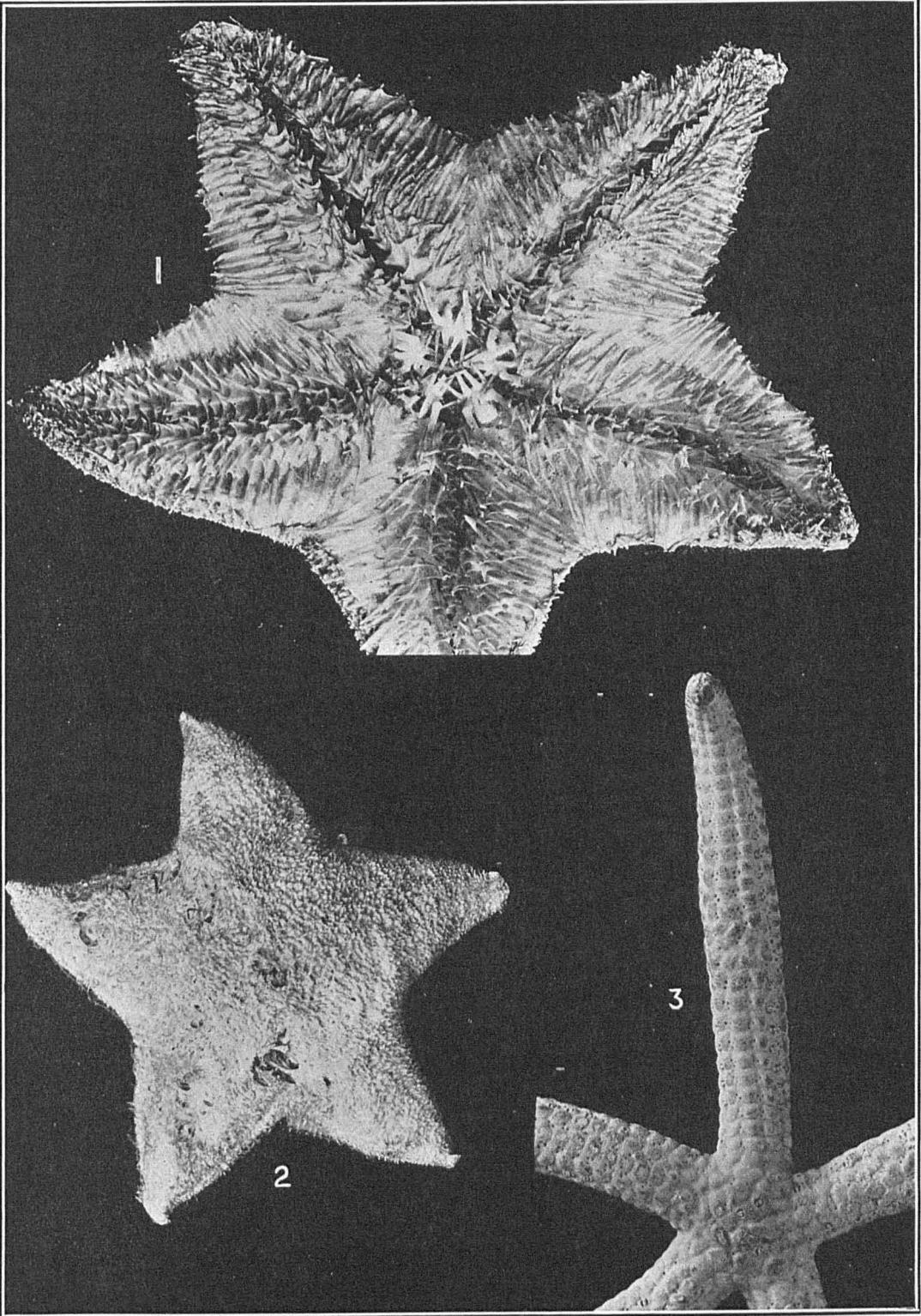
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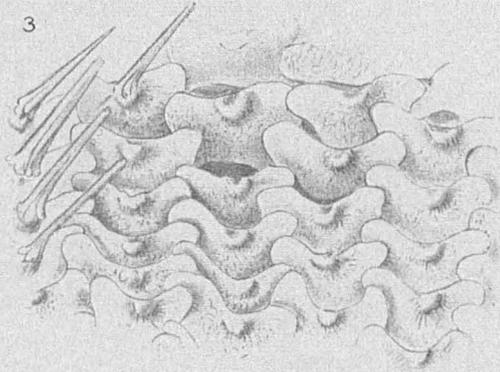
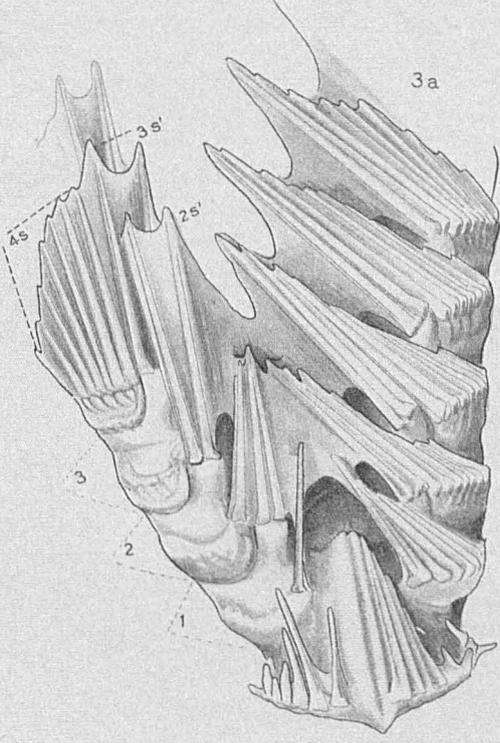
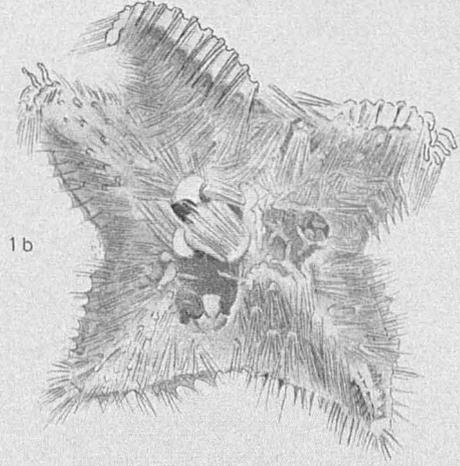
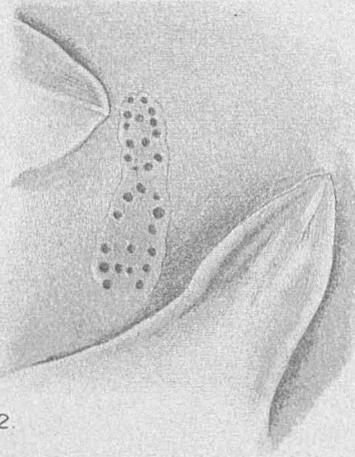
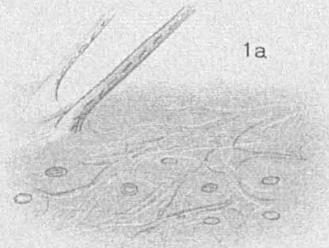
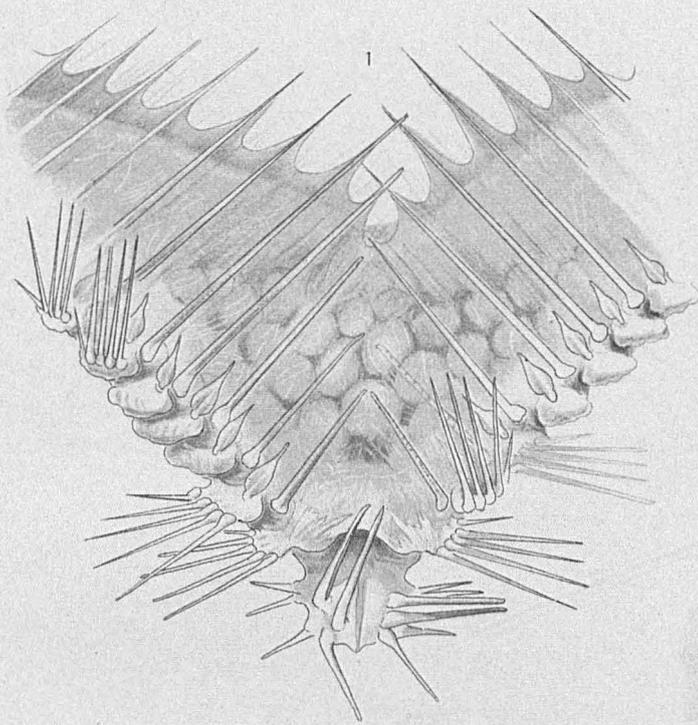


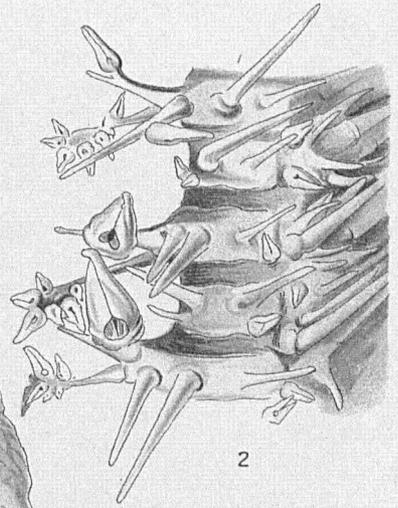








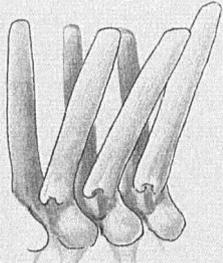




3a



4b



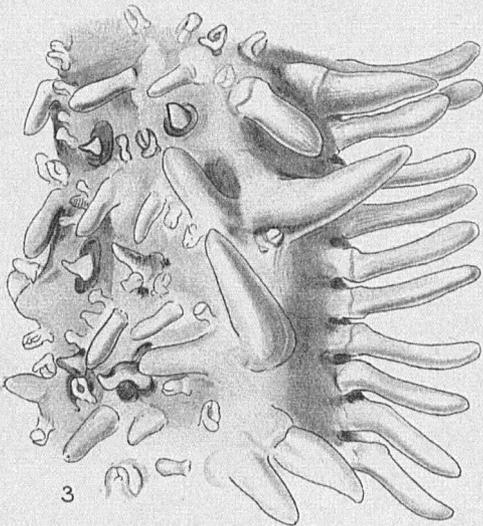
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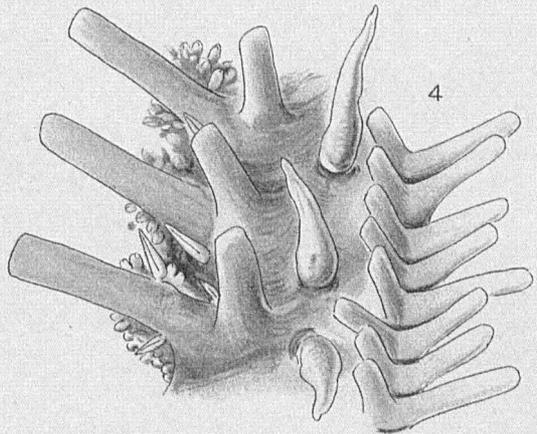
4c



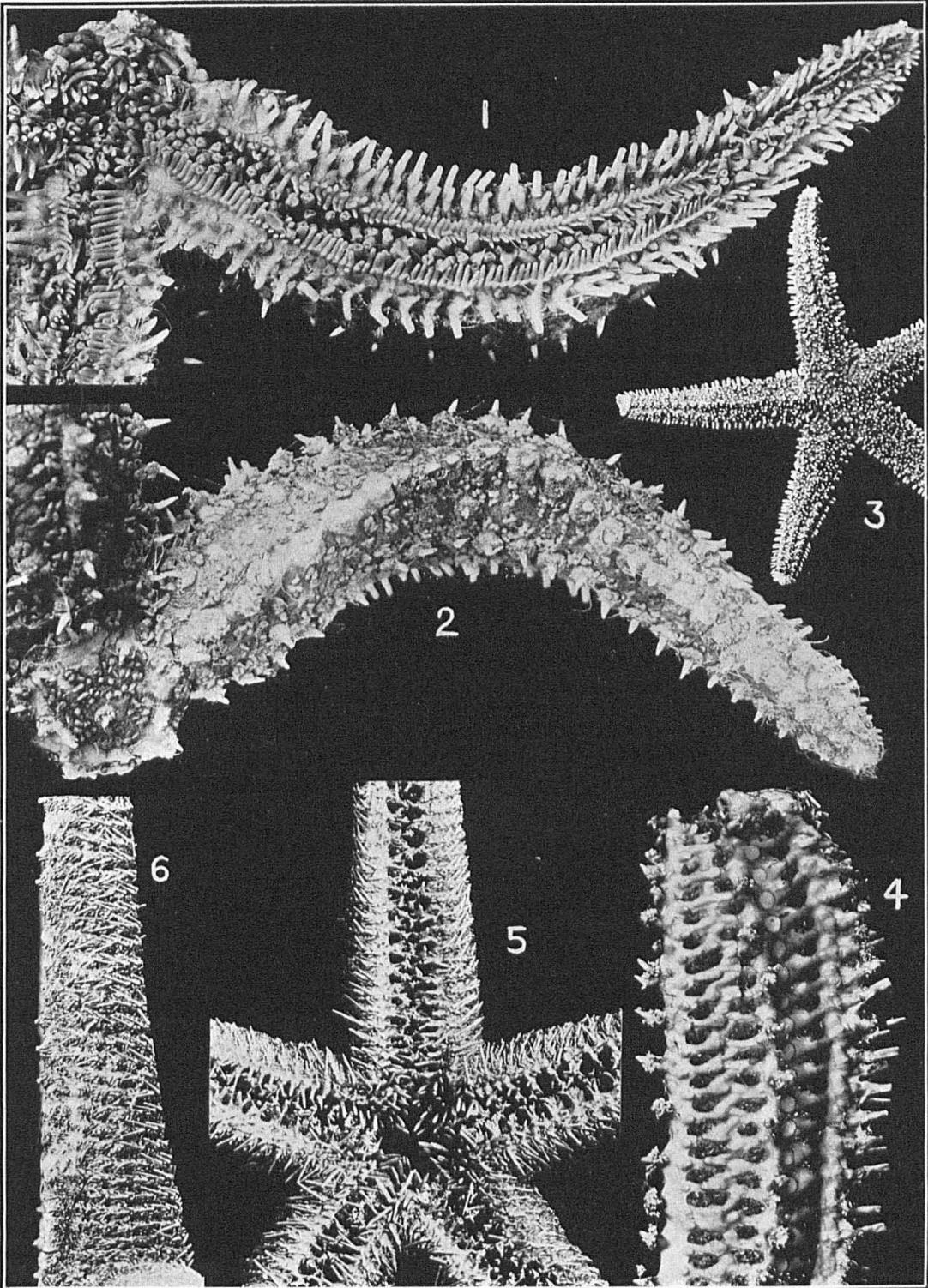
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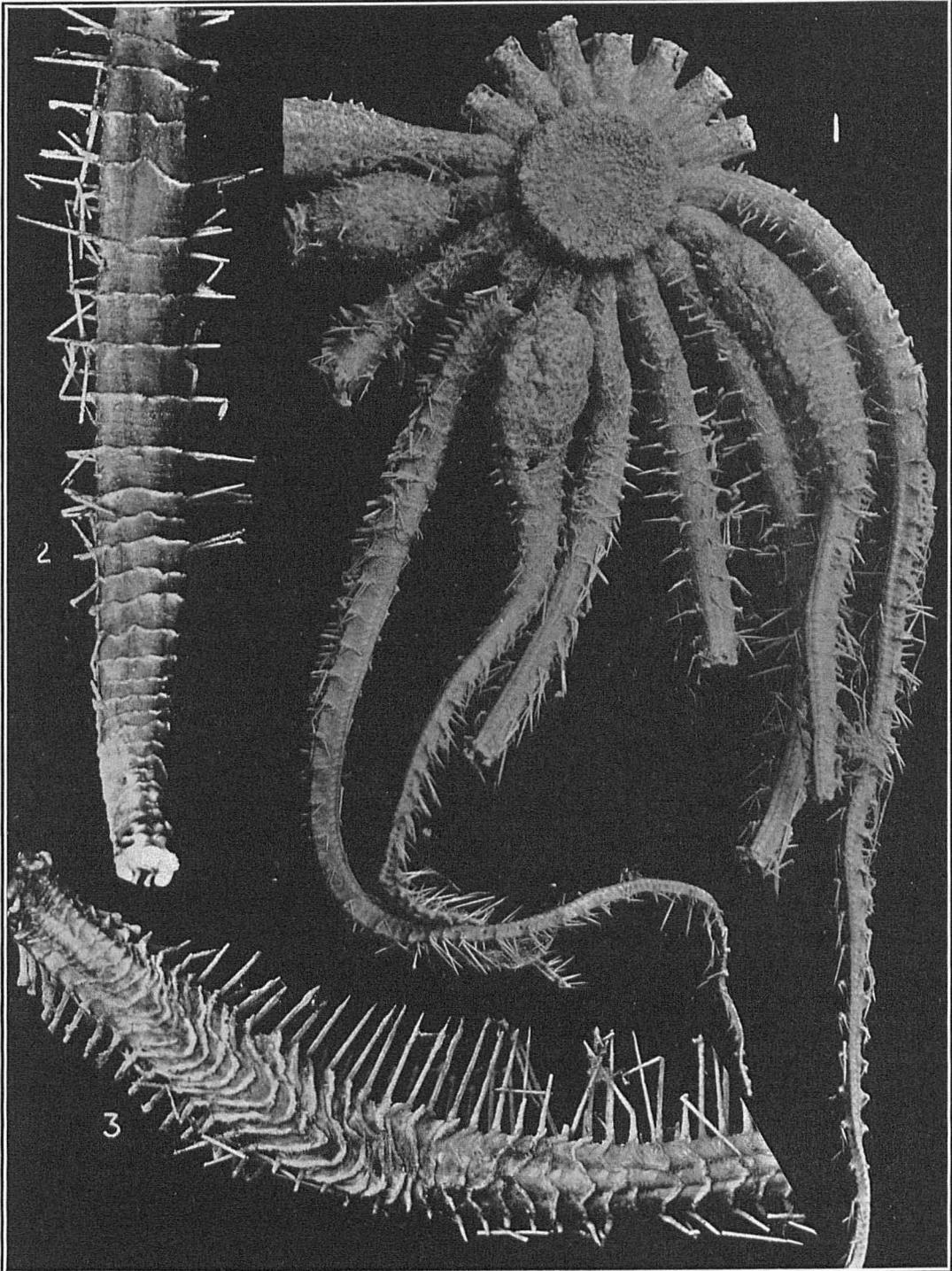


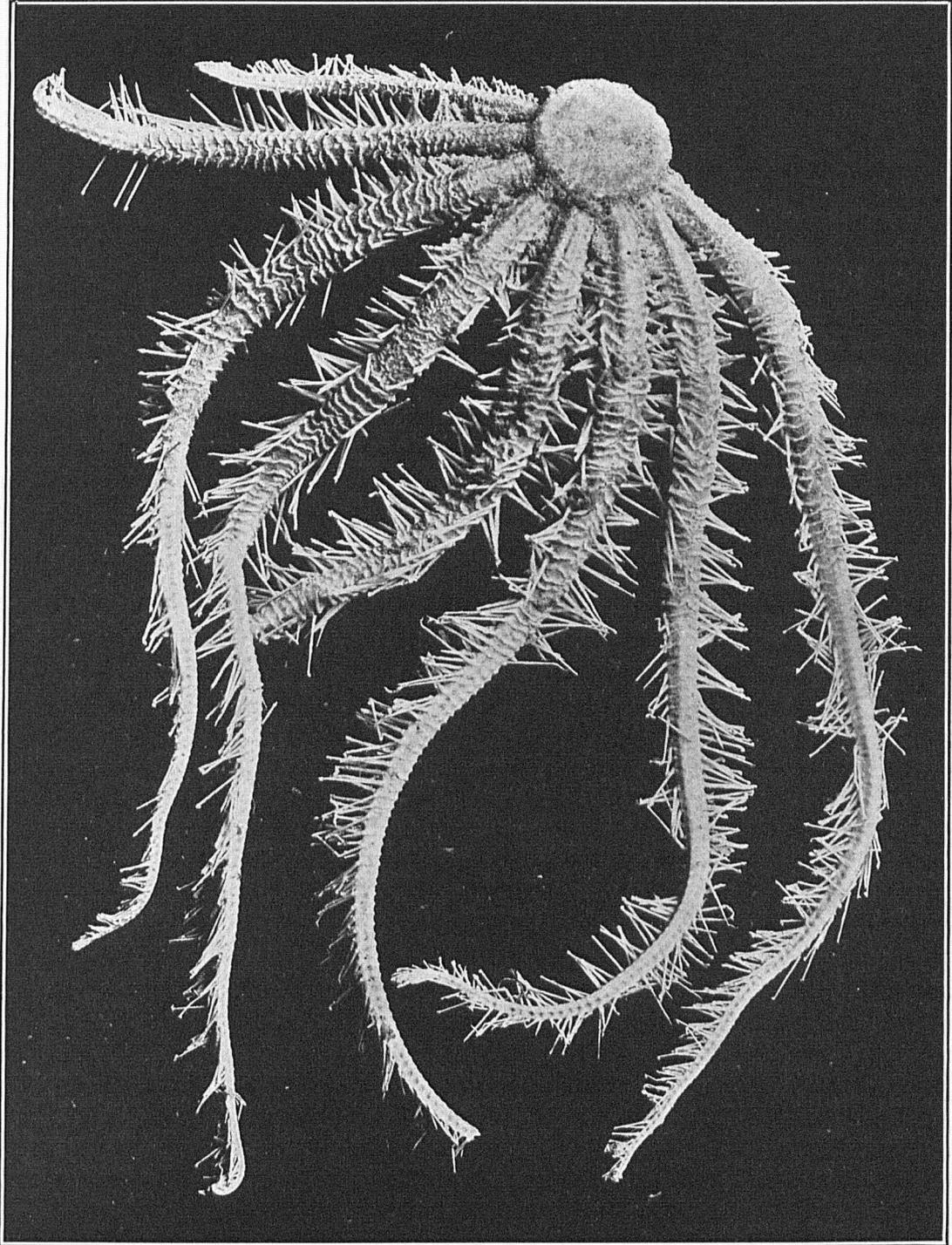
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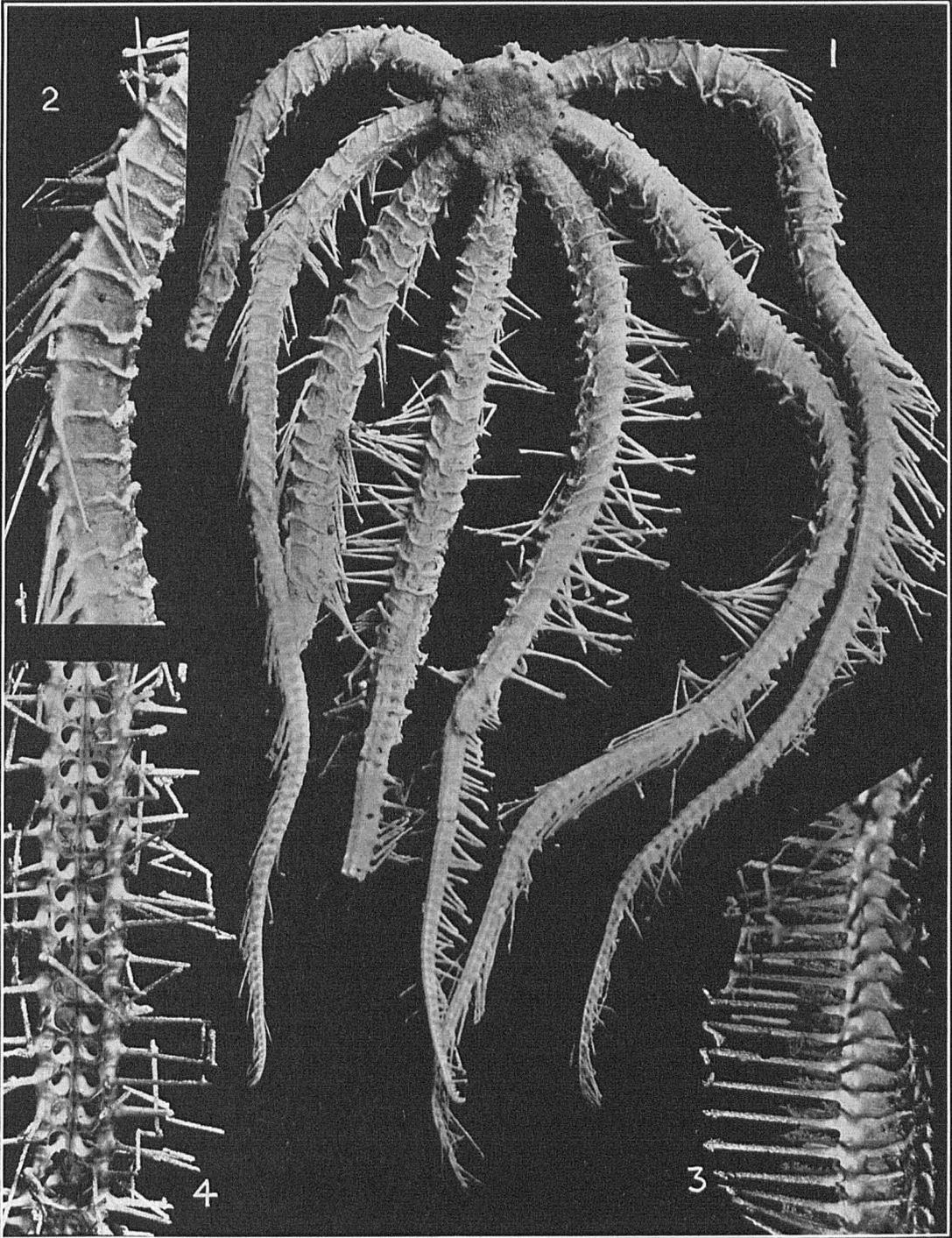


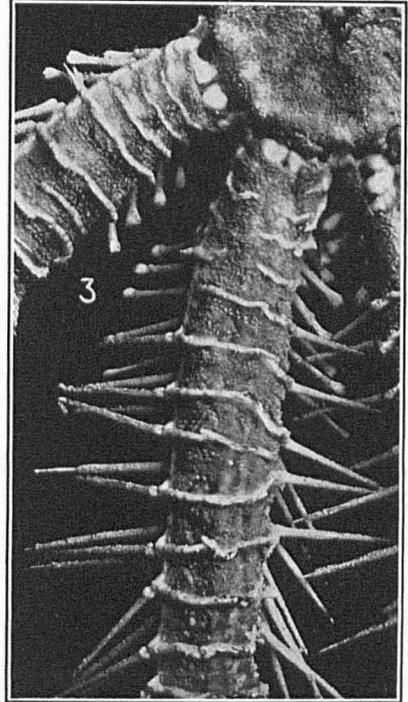
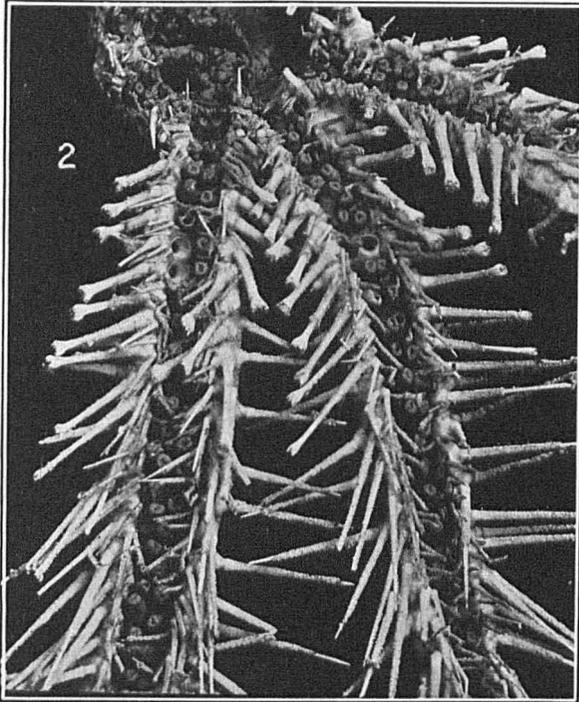
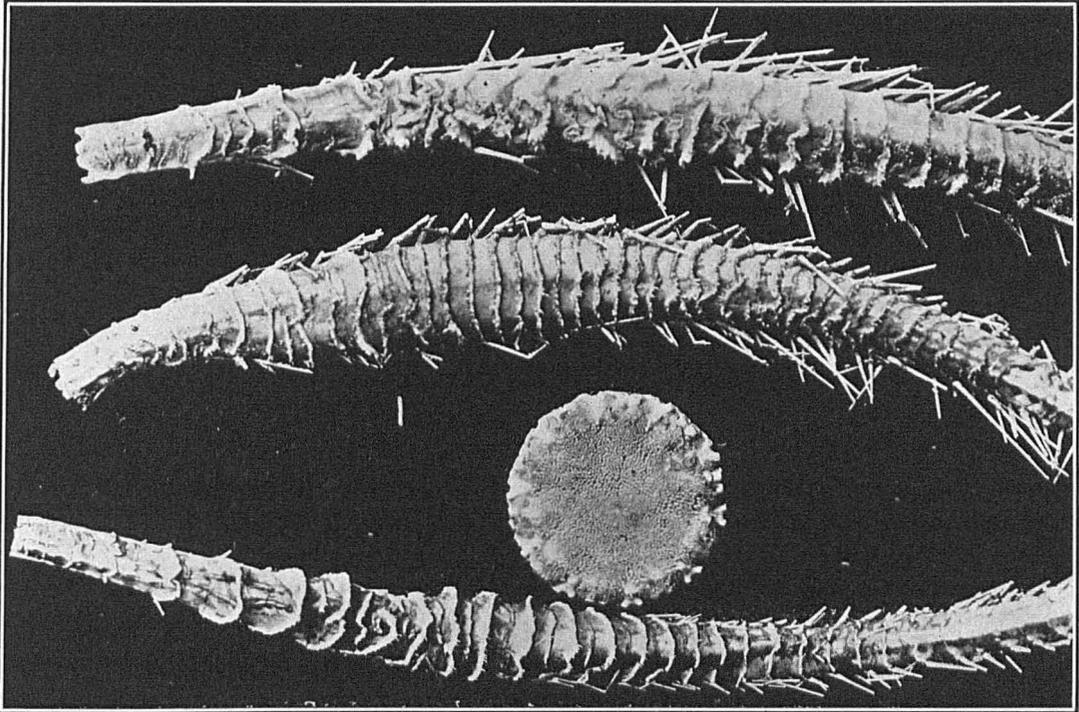
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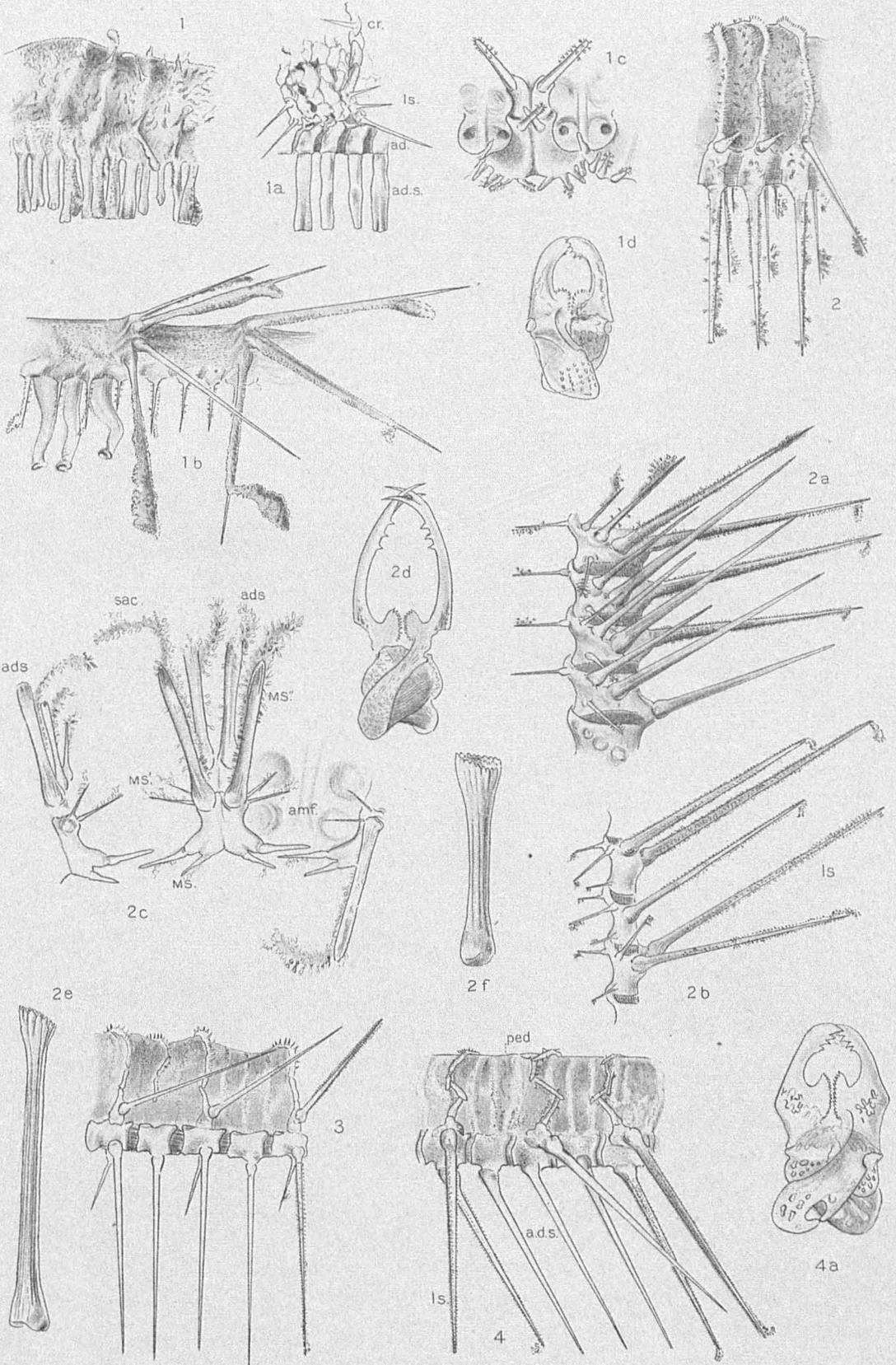


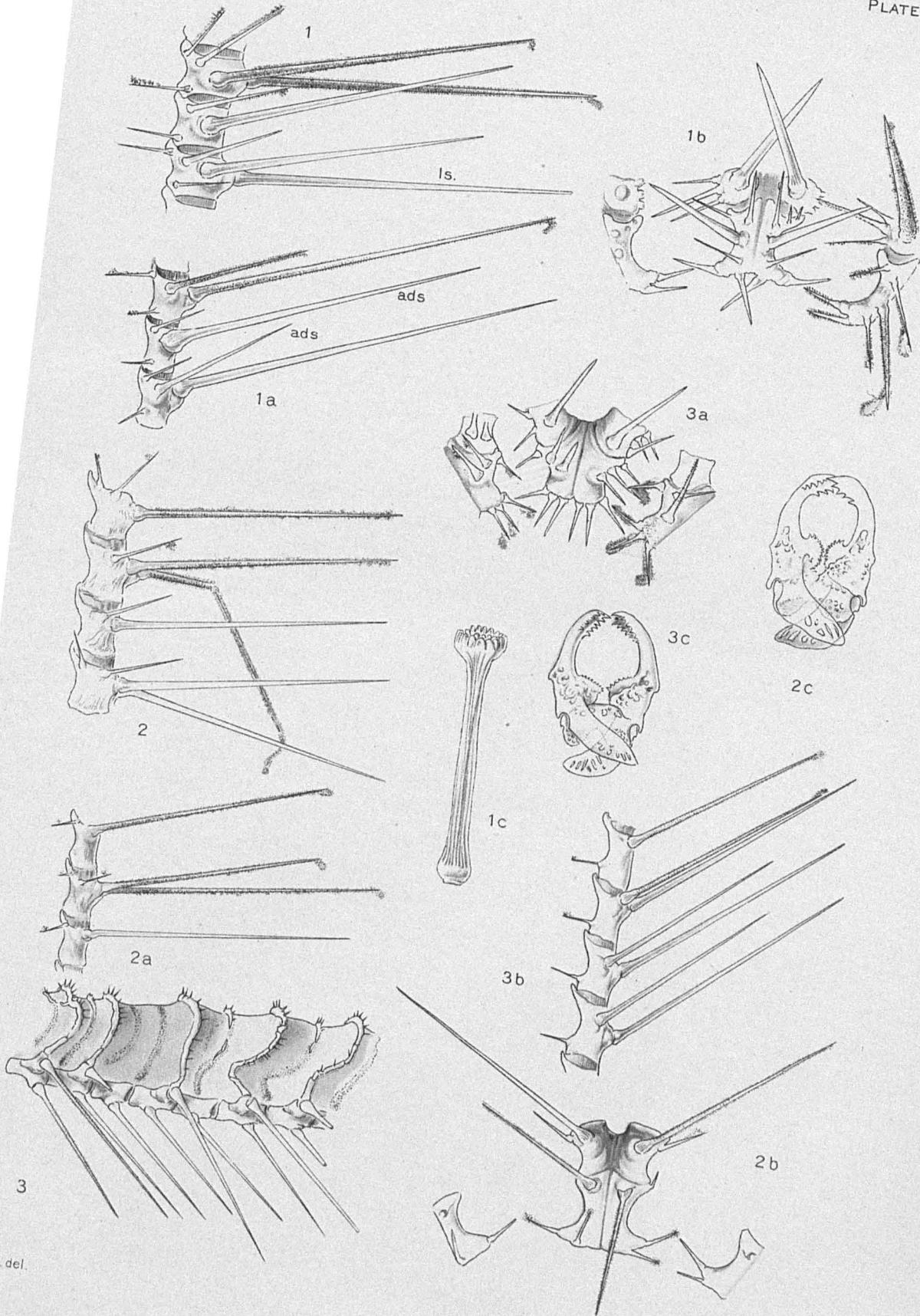












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